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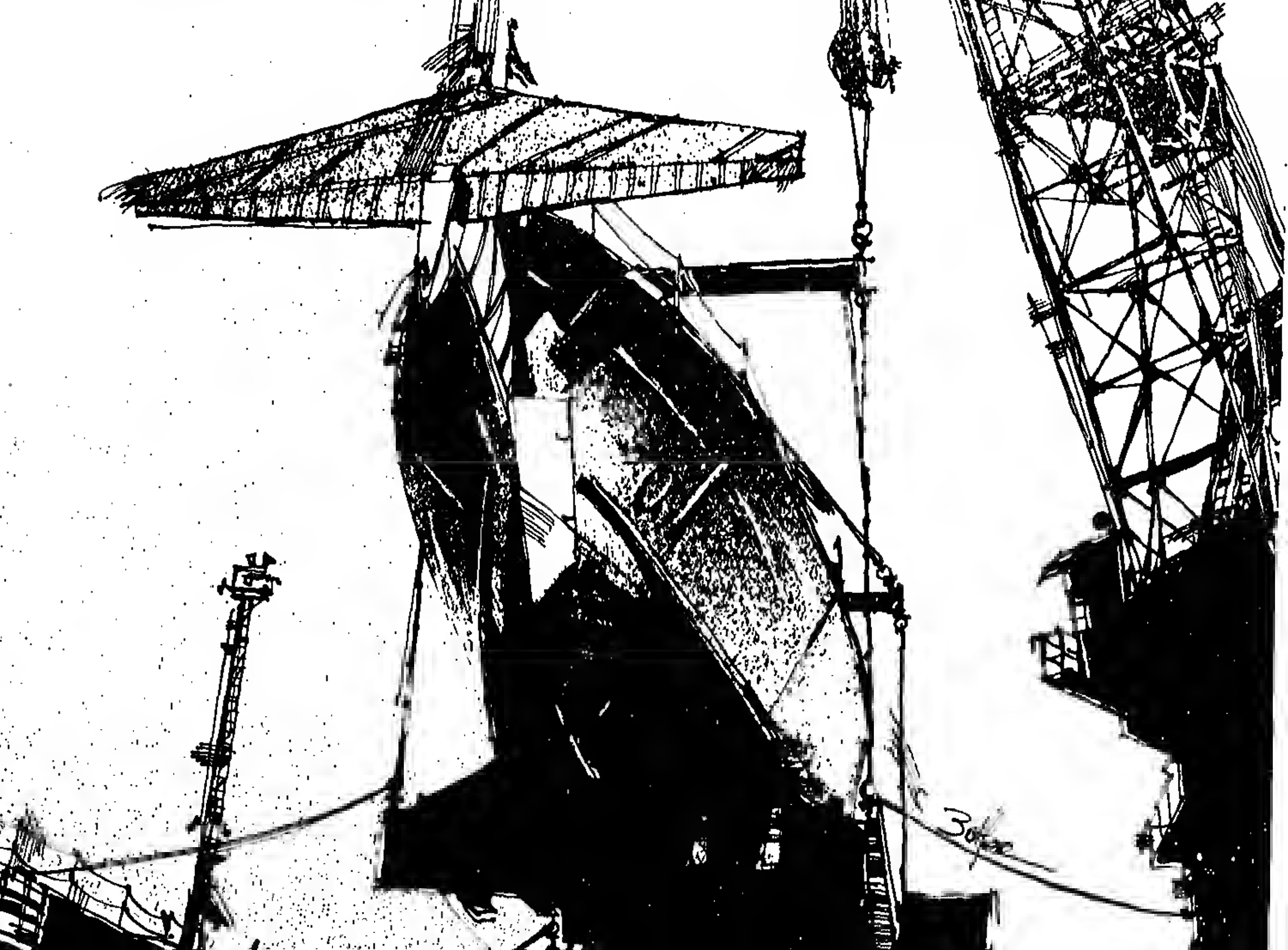
Quantifying seapower readiness

The ability to relate resources to ship readiness is essential to any credible assessment of the impact of budget changes on the Navy's fighting effectiveness.



budget submission data that would indicate the effect of the requested appropriations on material readiness. The same act also requested DoD to compile a report detailing measurable materiel readiness requirements.

As the Office of the Secretary of Defense began instituting these requirements, it identified several major problems that were obstructing compliance. In general, there were no clearly defined or agreed-upon measurable materiel readiness requirements. Although goals for operational readiness are specified by several services, such goals generally are not relatable to any analysis of the required combat capability for wartime missions. Even more disconcerting is the fact that OSD does not have an ability to project the effect of appropriations on materiel readiness.[1]

Therefore, Congress is not alone in its ability to benefit from an explicit, quantitative method for showing the effect of outlays for readiness. Navy decisionmaking would also be greatly enhanced if it were armed with such data. Simply put, readiness-related data were not made available to the Congress before 1978 because the Department of Defense did not have sufficient data to estimate the impact of various resource levels on readiness. However, a continuing research program might put the Navy in a position to answer many resource-to-readiness questions for ships.

Readiness-analysis problem

The readiness-analysis problem consists of defining readiness, measuring readiness, relating resources to readiness, and evaluating the importance of readiness. It is impossible to solve the latter two parts of the problem without addressing how to define and measure readiness. The inability to clearly define the readiness of a force or unit has traditionally inhibited readiness analysis. This problem can be resolved by concentrating on aspects of readiness we can effectively measure, and

readiness as *the ability of a force, unit, we system, or equipment to achieve a specif defined wartime objective,* others, including bers of the Department of Defense Read Management Steering Group, have defined *the ability of a force, unit, ship, weapon syst equipment to perform the function for whic organized or designed.* While these definition concepts are not really consistent, they are i related. Readiness includes material, perso training, and supply components. These deter the mission readiness of individual units. Ach ment of the ultimate goal—force effectiven requires consideration of such additional f as threat, force size, capability, and strateg readiness researcher must select which aspe readiness to analyze and evaluate. Whatever a is chosen, it must be appropriate to the situ and measurable, especially if an analysis reflect real-world rather than simulated data.

For example, in determining how to all funds for spare parts aboard a particular ship can focus on the material readiness of the sh perform its designated missions. However, pose a decision must be made between a ten mental, highly capable system and one that i ple but less effective. The ease or difficul achieving material readiness should enter int decision, but the analysis must not stop Even the inclusion of unit effectiveness i analysis may yield too narrow a perspectiv reality, before an accurate answer can be obta it might be prudent to model how groups of f are likely to interact in combat.

Measuring the readiness of ships

If ship readiness is measured solely in ter material readiness, analysts may avail them of the numerous data systems that concentra material condition. Two of these, the casual porting system and the maintenance and ma

indicating only a slight effect on the performance of one or more missions, to C4, the most severe, indicating substantial inability to perform at least one primary mission. Sometimes casualty reports in the C2 range that are filed aboard surface ships are used as a vehicle to expedite shipment of a needed part. This factor complicates the use of this system's data as a credible indicator of material readiness.

The unit reporting system extends beyond consideration of material condition. In the area of material condition, the system employs criticality diagrams to allow assessment of mission material readiness. The force status system, a predecessor to the unit reporting system, allowed considerable discretion to be exercised by commanding officers in assessing material readiness. This appears to be no longer the case.

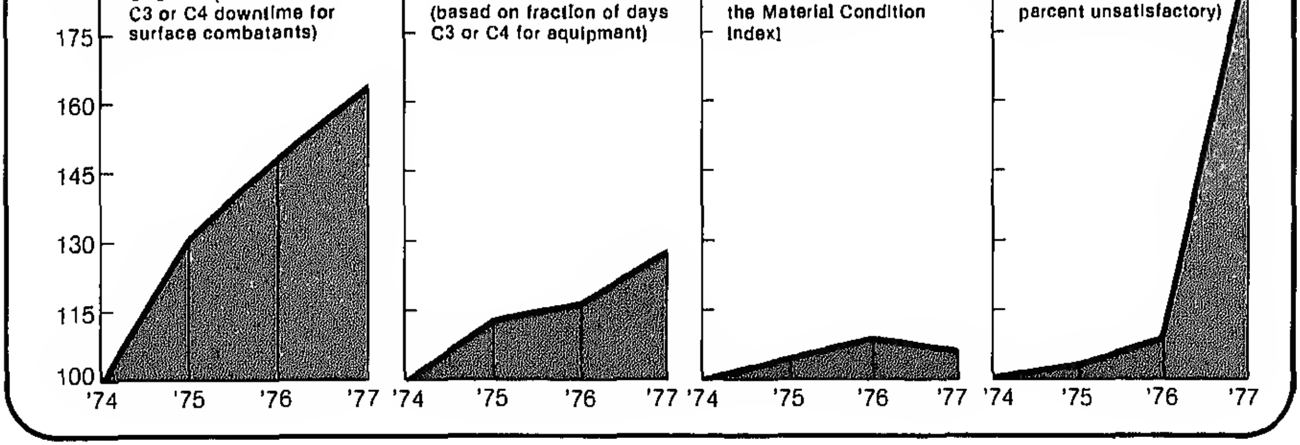
Two other systems produce readiness-related data from ongoing inspection programs. The Board of Inspection and Survey inspects more than 100 ships a year. After each inspection, the board assigns the ship a material condition index score which is the sum of grades in 25 categories including steaming, firefighting, combat, and habitability. The Propulsion Examining Board conducts inspections as part of the steam propulsion plant improvement program and has been inspecting specific classes of boilers since 1973. It grades ships according to materials, preservation, administration, knowledge, and casualty control. The materials segment of their findings is closely connected to material readiness. While the Propulsion Examining Board provides a summary rating, its inspections do not address the condition of weapons or of other non-propulsion equipment.

Finally, recent work shows that it is possible to develop data on material readiness from the engineering logs of surface ships. While this is a tedious task, the result is dependable. Interestingly, log entries noting out-of-commission equipment correlate well with casualty reports.

Both exercise and inspection results provide only snapshots of readiness and don't provide a mechanism to continuously track the readiness of a unit. Although the unit reporting system provides continuous measures of personnel, training, supply and overall unit readiness, the relationship between these indicators and the actual ability of ships to perform missions is still unverified.

Fortunately, it is not mandatory to measure readiness according to a particular definition in order to use that definition in an analysis. While pure statistical analysis requires real data, the usefulness of this approach is largely confined to studies of material readiness. At present, more effectiveness-oriented studies must rely on simulated data. If the simulation accurately reflects the details of the process being modeled, the output can be used to study readiness questions. Admittedly, effectiveness-oriented simulations exist, but seldom have they been developed or exercised with the purpose of uncovering and understanding readiness-related issues. At least for now, the scope of efforts to relate resources to readiness for ships must largely be limited to analysis of material readiness.

Even when an analysis is restricted to material readiness, most of the available data have some shortfalls. Much of the data is generated from reports ships make themselves, and self-reporting is not necessarily accurate reporting. Board of Inspection and Survey and Propulsion and Examining Board inspections are the cause of intense preparation that may not reflect the usual level of materiel readiness. The Center for Naval Analyses' cognizance of these shortcomings is reflected in its ship maintenance and supply study in which fleet-readiness trends from 1974 to 1977 were analyzed using four sources of material-readiness data. The results shown in Figure 1 compare the levels of the four material readiness indicators in 1977 relative to their levels in 1974. In each case, the higher numbers indicate improved readiness,



sources. All sources show improvement from 1974 to 1975, from 1975 to 1976, and from 1976 to 1977, except the Board of Inspection and Survey data which shows deterioration between 1976 and 1977.

Additional analyses were performed correlating different measures of material readiness across ships. Casualty report indicators have been compared with Board of Inspection and Survey and with maintenance and material management indicators; force status reports have been correlated with Board of Inspection and Survey results. Cross comparisons yielded significant correlations in all instances.

These analyses indicate that ships rated in good condition according to one indicator are likely to be rated in good condition according to others. Moreover, different indicators show similar trends over time. This consistency promotes the belief that existing data can be used to analyze material readiness if multiple data sources are used.

Relating resources to readiness

Reasonable indicators of material readiness can be derived from existing data. Similarly, statistical analyses that relate available resources for parti-

In FY76, an experimental program was implemented. Under the program 41 ships received unlimited funds to buy repair parts. A control group of 47 similar ships did not receive the unlimited funds. In FY77, the control ships began receiving increased funding, but not at the level of the 41 pilot ships. To measure the impact of the additional money on material condition, analysts used data from casualty reports and the Board of Inspection and Survey. The analysts performed a regression analysis that corrected for pre-program differences between the pilot ships and the control ships and for time trends independent of the program. Ship age was held constant, as were fleet type and ship type.

The analysis revealed that the pilot ships averaged 68 fewer days of serious C3 or C4 casualty report downtime per quarter. The control ships averaged 38 fewer days of downtime once they began to receive additional funds. In both cases, an $800 investment per ship resulted in a one-day decrease in C3 and C4 downtime. This result was verified using Board of Inspection and Survey data.

Another statistical analysis relating resources to ship material readiness highlighted the impact of the number and quality of enlisted maintenance

plant	Crew characteristic	level	level
Two screws, 1200 p.s.i.	Average score on shop Practices Test	55	56
	Percent E-4 or below	33	31
	Percent E-8 or above	3.8	5.2
	Percent with length of service under 1 year	6.9	5.8
	Percent with length of service 1-10 years	72.6	67
	Average number of school-related Naval Enlisted Classifications per man	0.46	0.49
	Percent unmarried	47	49
One screw, 1200 p.s.i.	Percent with length of service under 10 years	79.4	73.8
	Average number of Navy schools attended per man	1.9	2.07
Two screws, 600 p.s.i.	Crew size	22.4	23.1
	Percent with length of service under 10 years	79.4	73.8

or ratings, were analyzed and numerous potential indicators of crew quality were examined including education, entry test scores, paygrade, years of service, amount of sea duty, crew turnover, Navy schooling, marital status, and race. The study uncovered ways to improve the material readiness of boilers by increasing personnel quality or quantity (see Figure 2). One important finding was that higher skill levels are much more important in dealing with more complicated two-screw, 1200 p.s.i. equipment. The derived relationships can be used to predict the efficiency and effectiveness of alternative personnel policies about training and recruitment.

There are instances when resource-to-readiness relationships can be derived by using tools that are less complex than regression analysis. The possibility of halving the number of C3 or C4 casualty reports by easing the rules under which vital parts can be stocked aboard ship was identified by calculating the expected number of failures for various categories of parts on one particular ship. Additionally, simulation methods can be used to develop resource-to-readiness relationships. However, this approach is more common in the aviation arena and has been of less utility when applied to vessels.

model developed at the Naval Personnel Researc and Development Center. This model is a tot simulation of the interactions among personne equipment, and operational scenario. It is d signed to simulate the workload associated wi the normal activities conducted aboard a Na ship and it randomly samples events from empir cally derived frequency distributions. Even include assignment of crewmen to watches, mai tenance, administration, and support work; equi ment failures; training exercises and classes; an normal operations such as underway replenis ment and anchoring. The model can be used to te the implications of various manpower and perso nel policy decisions such as manning a ship with reduced crew or altering the paygrade or Nava Enlisted Classification distributions. With its abi ity to measure workload and derive material rea iness indicators, the model is a tool with which t assess the cost of reducing manpower levels Although the model does not adjust for qualitativ factoring by allowing more experienced people t perform repairs more quickly, it does have a wid range of applications.

Although there are many problems in identify ing and relating changes in a unit's level of re sources to its readiness, such relationships can b

funding aggregates that are visible at the budget level relate to changes in resources.

The implications of a budget change for the nature, quantity, and location of resources being bought are not always obvious. The impact of a budget change on a program depends upon where or how a given cut will be sustained. An across-the-board personnel cut will have a greater impact on readiness than a cut tailored to avoid critical ratings. Therefore, every budget change of major interest should be examined individually to determine which resources will be affected. Logic diagrams that aid this task can be developed, but the ability to automatically relate budget changes to readiness will be hampered by the uncertainty about where the changes will be made.

The difficulty of analyzing operational readiness is a major shortcoming that signifies an inability to adequately evaluate the contribution of many kinds of schooling and unit training to national defense. Unfortunately, the Navy has no yardstick against which to measure the contributions of operators, even though a ship is much more than a repair shop.

While relationships between resources and readiness have been developed, many important ones remain undeveloped or incomplete. The Navy now spends more than $2 billion on overhauls, and a study examining the effects of overhaul spending on the material condition of three classes of ships is only now nearing completion. The readiness implications of intermediate maintenance activities remain unanalyzed for ships. Indeed, much more can be learned about the contribution of improved supply techniques and better maintenance personnel.

Assessing the impact of budget changes

The goal of relating resources to ship readiness is the assessment of the impact of budget changes on the effectiveness of the Navy as a fighting

operational readiness are lacking. Perhaps engagement models could be useful in such instances.

Some feel that readiness has been shortchanged to increase the number and complexity of the weapons the Navy buys. Analysis to illuminate this issue would be timely and appropriate.

One reason we are not further down the path is that nobody is responsible for shepherding readiness research. Despite the fact that the Center for Naval Analyses has reviewed over 130 readiness-related studies, there is no central point for tracking these studies, identifying areas that have been well researched, selecting the most promising areas for new research, or converting research findings into management tools. To remedy these deficiencies, the Navy should examine the possibility of designating a single office to monitor and manage future research on resource-to-readiness relationships and readiness trends; coordinate responses to readiness questions; and act as an advisory board to the Chief of Naval Operations on readiness matters.

The development of models to improve management and fulfill congressional requirements is a long-term effort. In the meantime, questions on readiness will have to be answered on a case-by-case basis. An office dedicated to ensuring that the answers are related to a coordinated, ongoing research program would certainly make the job easier. DMJ

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The Army's approach to improved strength forecasting

The ability to forecast Army strength and recruit the number and type of volunteers needed is essential to defense policy development.

force; the ability to modernize it quickly enough to ensure that we are able to be competitive with the Soviet Union; and the ability to be able to mobilize and sustain ourselves if we are called upon to have to carry out any of our war plans.[1]

Support for two of these areas, manning the force and mobilization, is provided by the Army's ELIM-COMPLIP (Enlisted Loss Inventory Model-Computation of Manpower Programs Using Linear Programming) computer system. The system's principal output is the Active Army Military Manpower Program, which presents forecasts for various categories of strength, gains, and losses. It also forecasts monthly requirements for initial training for the current and six future fiscal years.

The ability to forecast Army strength is essential to defense planning, policy development, and budget formulation. The ability to recruit the number and type of volunteers needed to maintain Army strength at the level prescribed by defense policy is a prominent issue. So is the possible resurrection of the draft. Clearly, the ability to accurately forecast manpower strengths that reflect proposed policies, programs, and budgets is extremely valuable.

The accurate forecasting of Army strength generally requires projections of:

- Availability of prospective enlistees under a variety of policies and projected economic, social, and political conditions.
- Attrition losses.
- Reenlistments as a function of Army personnel policies and external conditions.
- Various categories of strength, including operating strength (the number of soldiers in the units that make up the Army force structure), and individuals accounts (soldiers in training, in transit, in hospitals, or otherwise unavailable for assignment to units).

strength is what Congress bases authorization and funding decisions on. Army planners examine total and operating strengths when they consider what force structure the Army can man within the congressional strength limitation and when they consider how closely operating strength will match the number of soldiers authorized to be in units.

Strength projections are used to determine the dollars needed by the Army to cover personnel cost. Pay and allowances, subsistence, housing, travel, entry training, recruiting, and bonus payments are all functions of strength projections. A two-percent projection error, which is well within the acceptable accuracy for many forecasting procedures, represents a budgetary impact of more than $200 million. This is enough to cover the annual operating costs of one of the Army's 16 combat divisions.

Since becoming operational nearly nine years ago, ELIM-COMPLIP has demonstrated the accuracy, responsiveness, and flexibility to contribute significantly to the formulation of personnel policy, the monitoring of progress against goals, budgeting, and force planning. Now in its fourth generation, the system produces total-strength forecasts that are accurate within 0.5 percent. Figure 1 (p. 10) reflects the percent error of forecasts of total enlisted strength three months ahead of the latest available actual strength data. Errors are plotted for eight monthly updates produced by ELIM-IV and the corresponding data for ELIM-III. All of the errors are within 0.5 percent. Similar accuracy is obtained for projections 12 or more months beyond the latest actual strength data. Figure 2 (p. 11) shows the mean absolute percent error for forecasts of total enlisted losses from 1 to 36 months ahead of the last historical data.

The initial version of COMPLIP was developed over a one-month period between December 1969 and January 1970 in response to a request from the

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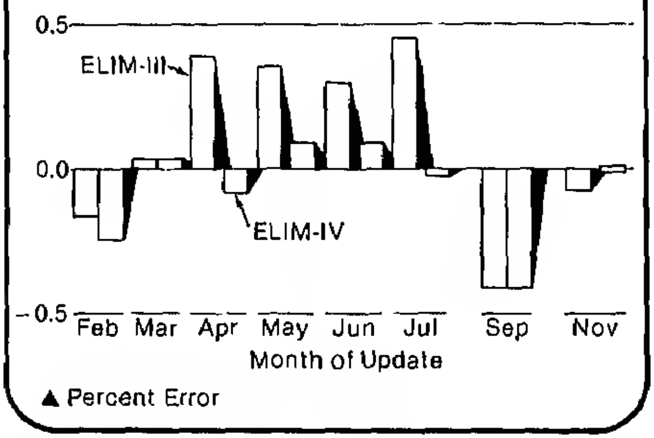
[1] *Department of Defense Appropriations for 1981, hearings*

Editor's note: This article is adapted from a paper pub-

is obtainable for 12-month projections as well.



Assistant Secretary of the Army (Manpower and Reserve Affairs) for a tool that would enable examination of alternative manpower programs associated with Vietnam- and draft-related plans and policies. The request was for a computerized procedure to replace manual methods that were too slow to keep pace with the growing volume of *what-if* questions. COMPLIP provided the needed responsiveness, and because of its optimization methodology, produced results that were measurably better than those produced by manual procedures. In one of its first applications, COMPLIP showed how the Army could adjust strength to a phase-down schedule with a savings of 5,000 man-years. Subsequently COMPLIP showed how variations in draft calls could be controlled so as to avoid unacceptable sacrifices in strength. It also provided projections of both draft-induced and volunteer enlistments.[2]

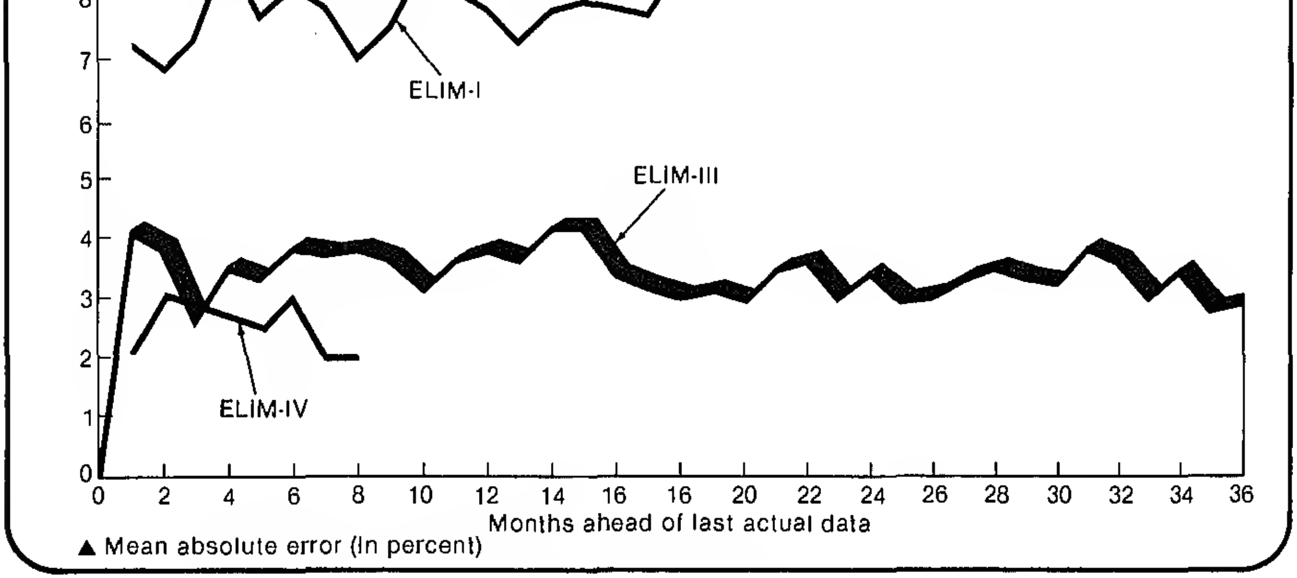
COMPLIP is designed to determine those gains the Army needs to maintain operating strength in closest possible agreement with authorization targets. COMPLIP is a linear-programming model, or more specifically, a goal-programming model, that minimizes the weighted sum of the mines the active Army inputs to basic training each month. A second solution then uses any residual training capacity to schedule the active-duty training of Reserve personnel. The optimization is subject to a variety of user-specified constraints such as limitations on various kinds of gains and on strength and manyear ceilings.

During the early usage of COMPLIP, the projection of manpower losses was introduced into the manpower program through the automation of manual procedures that had been developed several years earlier. This procedure was reasonably effective during the 1960s when Army strength was increasing. However, by October 1971, projection errors associated with this procedure had led to an Army of significant overstrength at a time when Congress had imposed a strength ceiling that was significantly lower than what the Army had anticipated. To improve loss-projection capabilities, the Army launched an intensive effort that resulted in the development of ELIM which was linked with COMPLIP. The hybrid system became operational in July 1972.[3] ELIM forecasts losses by applying loss rates to corresponding enlisted-strength elements that are obtained by partitioning data representing the current personnel inventory and then projecting the inventory through time.

ELIM-COMPLIP is a tightly integrated system consisting of six major modules. There are two types of inputs to the system: automated files, such as records maintained in the Army's personnel accounting system, and user inputs, which specify policy constraints and controls affecting forecasts of loss rates. Considerable design effort has been devoted to providing the flexibility needed to examine policy alternatives and to keeping the user effort within manageable limits. This ensures that the sytem will be responsive to requests for generating alternative manpower programs within a period of several hours.

[2] *Paul D. Phillips,* Manpower Models for Force Structure

[3] *Betty W. Holz,* The ELIM-COMPLIP System of Manpower Planning Models, volume I: General Overview, *Gen-*



The rate generator is designed to project loss rates that can be broken down into 10 loss categories and roughly 4,000 population categories, some of which can be defined by the user in terms of demographic and operational variables associated with recruits. The loss rates are derived from exponential smoothing of time series of historical rates. Where appropriate, exponential smoothing with seasonal adjustment has been used. Also, the option of projecting trends or step adjustments under user control to reflect the effect of external factors such as policy changes or environmental conditions is provided. Initially, there was much concern about the feasibility of managing a system having so many loss rates. However, its operability has been ensured through design features that provide for monthly automated updates of the data base, user intervention only on an exception basis, automated means of alerting the user to conditions requiring attention, and detailed procedures for reducing the labor required to input user controls.

Inherent in the COMPLIP linear-programming technique is a considerable amount of flexibility that permits selection of constraints and objective generator that tailors the model to the user's specifications, which include congressional strength limitations, projected availability and seasonal patterns of user-specified categories of accessions, and recruitment policies influencing the composition and quality of recruits.

The effect of external factors is handled differently in the projections of losses and gains. The automated projection of losses is based on factors associated with the personnel in the force. Changes in non-demographic factors are reflected in some type of systematic variation in time series of affected loss rates. For example, there was an observed decrease in desertion rates following the withdrawal from Vietnam, with the user projecting the trend to continue until the rates reached pre-Vietnam levels at a specified date. User controls also have been directed at the projected effects of policy changes, with rates automatically adjusting to expected levels following the policy change. This procedure has been used in addressing changes in reenlistment policy and programs for the discharge of marginal performers.

On the other hand, the projection of enlistments

nonlinear regression with the regression being linear in two categories of explanatory variables: econometric variables over which the Army has no control, such as unemployment rates, military-to-civilian pay ratios, and size of prime recruitment pool; and policy variables over which the Army does have control subject to congressional authorization, such as extent of recruiting effort, enlistment options, and bonus programs. These linear terms are multiplied by factors that reflect seasonal fluctuations, and separate projections are made for each user-defined group such as male high-school graduates in the highest test score category.

Another key feature of the system design is the linkage between the very detailed computations of the first three system modules (the data processor, rate generator, and inventory projection module) and those of the optimization module, which for reasons of computational feasibility must be considerably more aggregated. Specifically, the enlisted inventory is partitioned in the inventory projection module, as are the loss rates and other data supplied by the rate generator and data processor. The population cells of the inventory projection module are projected month by month, with gains added, losses subtracted, and indexes adjusted to reflect the passage of time. However, for enlisted inventory elements associated with gains whose quantity is determined by the COMPLIP optimization procedure subsequent to the projection module's run, the module computes retention rates that become coefficients for the linear program-

sistent with both the projection module's detailed projections and COMPLIP's subsequent determination of optimal gains.

Perhaps the most significant features of the ELIM-COMPLIP system have been the ability to quantify strength-related impacts of proposed policy changes and the ability to foresee the future effects of emerging programs and trends. These capabilities have led to improved decisionmaking and the implementation of preventive actions before the onset of crisis.

An illustrative case in point occurred shortly after the adoption of the all-volunteer Army, when ELIM data alerted officials to a sharp increase in the desertion rate of soliders who were in their eighth month of a 4-year enlistment. The increase in desertions was traced to soldiers who had received bonuses for enlisting in the combat arms. At that time, this bonus was awarded at the completion of initial training, just before the soldier reported to his first unit assignment. Following this analysis, this bonus payment was deferred until the soldier reported to his unit.

Additionally, based largely on an analysis of ELIM data from FY72 and FY73 enlistment cohorts, Army officials restricted eligibility for this bonus to high-school graduates. The analysis revealed that of all person-related variables, civilian education was clearly the most valuable for estimating attrition over the first nine months of service. It was found that only 10 percent of high-school graduates attrited in the first nine months, as opposed to 24 percent of non-graduates with

influence of civilian education on attrition has been substantiated by similar analyses of the other services.

The improved accuracy of ELIM-COMPLIP forecasts has also contributed to improved forecasts of budgetary requirements and allocations. Consequently, an estimated 100 to 200 million dollars that were previously required each year as a hedge against uncertainty in forecasts are now available for alternative uses.

In the area of force planning, the contribution of ELIM-COMPLIP was highly evident in the 1974 initiative to expand the active Army to 16 divisions. The Senate had passed a bill directing a reduction of support troops stationed in Europe but had authorized retention of these soldiers if they were assigned to combat units. The draft had ended and the Army had achieved its authorized strength through volunteer enlistments. Attrition was decreasing and reenlistments were increasing. The average length of service of new soldiers was increasing as the gains to the enlisted force shifted from 2-year draftees to 3- and 4-year enlistees. ELIM-COMPLIP was forecasting a requirement for fewer new enlistees, with a corresponding reduction in the individuals accounts and a reduction in the number of soldiers required to train these new enlistees. Considering all of these factors, ELIM-COMPLIP projected that in two years, operating strength would increase by about 40,000 if the total strength of the Army remained at 785,000.

Of course, it was necessary to ask whether these divisions that the Joint Chiefs deemed necessary. History tells us they were.

Today the ELIM-COMPLIP system supports the Army's mobilization planning, including the development of alternative manning plans for mobilization. If a national emergency were to spur resurrection of the draft, output from ELIM-COMPLIP would help officials determine the required number of draft calls and orchestrate the call-up of reserve-component personnel.

Clearly, the ELIM-COMPLIP system, by applying management-science technology to personnel management, will continue to make a valuable contribution to the development of Army plans, programs, and policies. DMJ

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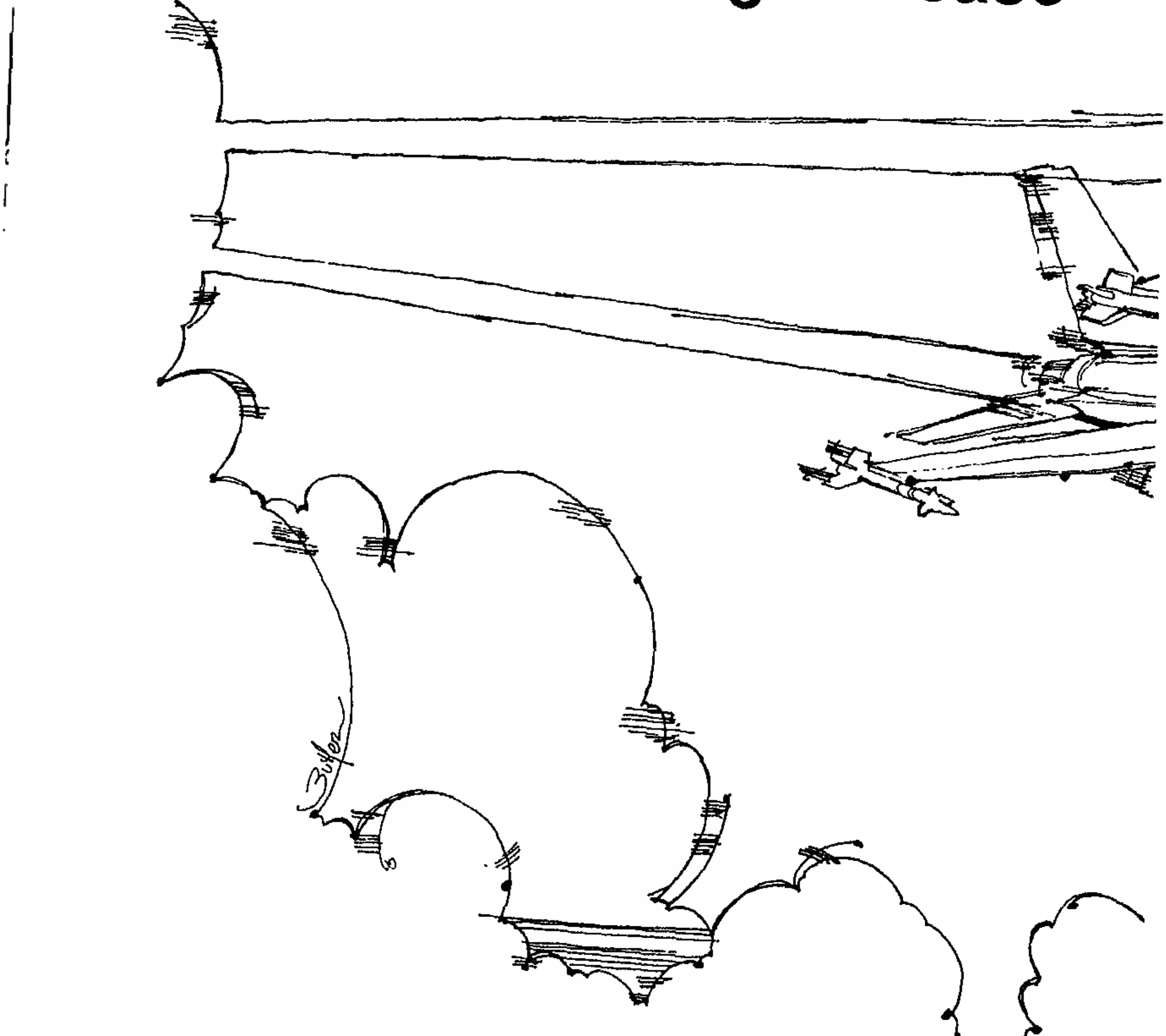
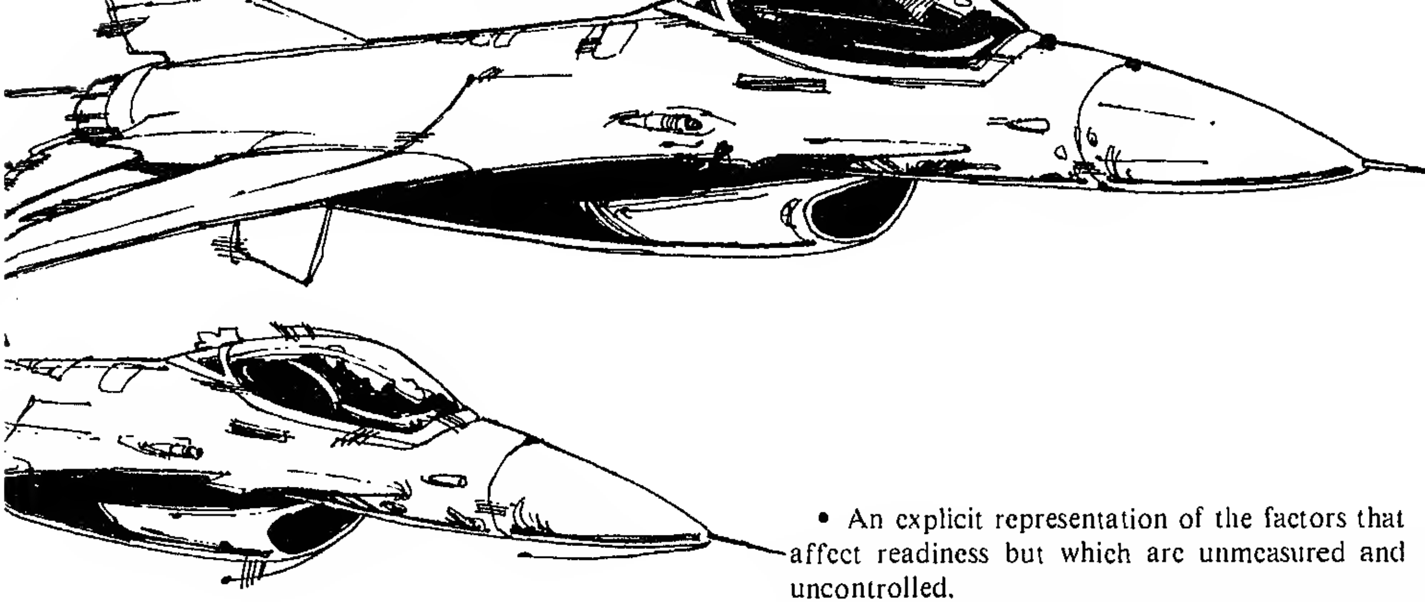
the tactical-fighter case



By JOHN B. ABELL

A recently developed hybrid analytic-simulation



The need to relate resources to readiness—the ability of military forces to perform their assigned missions—is a principal concern of Congress and the Department of Defense. In the FY78 Defense Authorization Act, Congress stipulated that future DoD budgets include data that project the effect requested appropriations will have on readiness.

Approaches for estimating readiness as a function of resources might be said to be of two kinds. The first includes econometric models that depend on regression analysis of data reflecting historical or empirical observations of resource expenditures and military readiness. This type of approach is made extremely difficult, perhaps impractical, by the need for:

• Historical data that reflect significant variability in levels of resources and in the measure of readiness.

• An understanding of the dynamic interactions of the allocation, expenditure, and commitment of

• An explicit representation of the factors that affect readiness but which are unmeasured and uncontrolled.

Some analysts believe that regression analysis could be used to build useful cost-estimating relationships that would apply to the resources-to-readiness estimation problem. Indeed, there is strong motivation for doing so because cost-estimating relationships could be powerful and convenient tools in the resource-allocation process. Unfortunately, the feasibility of this approach has yet to be demonstrated.

The second kind of approach postulates mathematical models of processes, relationships, and resources, typically at a detailed level. Detailed data are required and the models employed tend to be tedious, cumbersome, and costly; however, such models might also be used to construct cost-estimating relationships. Thus, while the two approaches are fundamentally different in character, each is a means to the same end. Some of these models are analytic models; others are simulation models; still others are hybrid, boasting some of the computational speed of analytic models and the flexibility of simulation models. The Logistics Management Institute's sortie-generation model represents a hybrid analytic-simulation model that is an example of a micro a roach that models the

readiness as a function of resources. The approach is of particular interest to defense managers because it may well be extendable to other force types and mission categories.

Dimensions of readiness

Military readiness has two dimensions. The first is the *responsiveness* of a military force, a dimension that is especially important to a *one-shot* threat. For example, the effectiveness of an air-defense force against a manned-bomber attack depends heavily on its initial responsiveness to an attack. The requirement for massive, quick response characterizes some air-defense scenarios. A second dimension of readiness comes into play when one considers a prolonged interdictive campaign conducted by tactical fighters. This second dimension is *sustainability;* and, while the dimension of responsiveness is still present, the sustainability of the force clearly dominates the assessment of its readiness.

In the case of tactical fighter aircraft, the most direct and meaningful measure of readiness is maximal sortie-generation capability across time. It reflects both responsiveness and sustainability. The sortie-generation model produces a profile of the average number of sorties flown on each wave of each day over the duration of a scenario of interest, where the average is taken over some specified number of experimental replications.

The sortie-generation model system consists of the model and a complex system of supporting software. The software system consists of two subsystems, the spares subsystem and the maintenance subsystem. Data and resource allocations from these two subsystems are combined in data bases that are used as input to the sortie-generation model (see Figure 1). Together, the model and its software provide a means for allocating funds to recoverable-spares procurement and repair that takes explicit account of the military essentiality of

that represent an *average* air base having typical features and components such as aircraft, maintenance manpower, quantities of spares, work centers, and so forth. These configurations, or notional bases, support analyses that may be extended directly to a force of aircraft of a given model-design-series. Finally, the sortie-generation model is designed to preprocess and distill for its own use data from a variety of standard Air Force data systems.

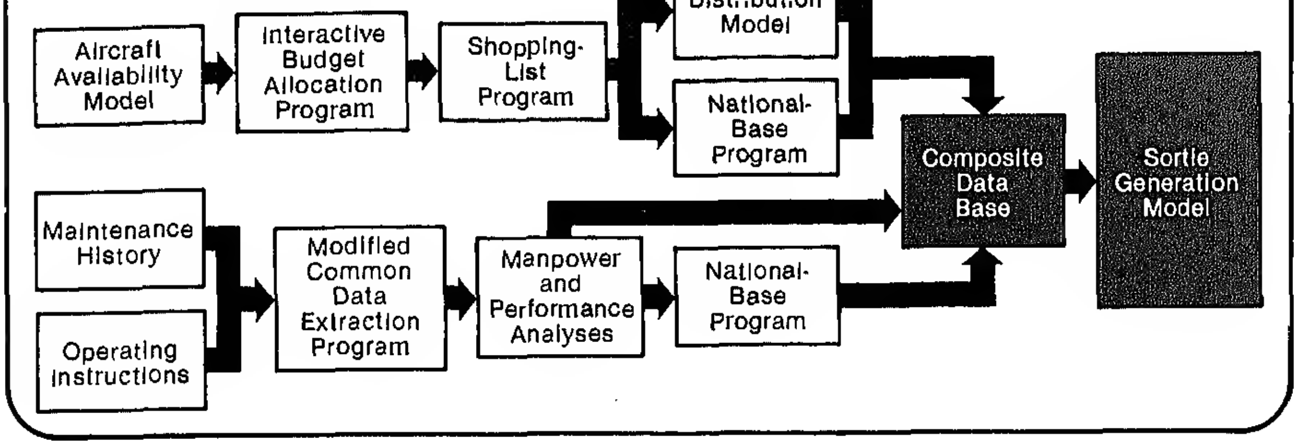
The sortie-generation system models the transition of aircraft from one operational state to another. There are five such states:

- Mission capable.
- In or waiting for maintenance.
- Waiting for parts.
- Lost in combat.
- Held in reserve.

The first and last takeoff times of the day and the number of flying periods are specified by the user. The system divides the flying day into the specified number of periods and makes them of equal length. The sortie length and the minimal time required to launch a mission-capable aircraft are also user-specified and are built into the daily schedule by the system.

A sortie-generation profile that is typical of

Simply put, the model offers a workable approach to the problem of estimating readiness as a function of resources. The approach is of particular interest to defense managers because it may well be extendable to other force types and mission categories.



constrained resources coupled with a two-percent aircraft attrition rate. These profiles resulted from a scenario that required five mass launches each day.

Spares subsystem

The spares subsystem consists of five primary components. Each is addressed below.

Aircraft availability model. The sortie-generation model system builds upon and extends the aircraft-availability model, a state-of-the-art, multi-echelon inventory model developed, validated, and refined at the Logistics Management Institute. The availability model produces an availability-versus-cost curve for each model-design aircraft, for each model-design-series of aircraft, and for any combination of the two. Given the assumptions made in the model, each point on the curve is an optimum representing the least-cost mix of spares and depot-level repair for the level of aircraft availability. It also represents the maximal availability achievable for the total cost of procurement and repair.

The availability-model data are derived from the Air Force Logistics Command's DO41, DO41A, and KOO4 data systems. For each recoverable item in the system, the data specify the current stocks, failure factors, pipeline times, flying-hour programs, item application by weapon system, base repair fractions, item unit costs and repair costs, and other factors that shape the resource-allocation solution and resulting mix of spares. The availability model estimates the effects of lateral resupply and takes explicit account of item commonality—the application of a component to more than one kind of aircraft. In short, the model is a powerful, flexible, resource-allocation tool for recoverable-spares procurement and depot-level repair.

Interactive budget-allocation program. The interactive budget-allocation program enables the user to specify the amount of money he wishes to allocate to each model design. He does this by specifying an availability increment or budget increment, either positive or negative. The program then displays the current budget allocation and availability for each model-design and the budget allocation and availability that would result from applying the increment or decrement to each model-design. Additionally, it monitors and displays the funds allocated to the entire force, a total that includes the sum of dollars for procurement and the sum of dollars for depot-level repair. The two values are optimized beyond the control of the user.

costs are at any point in the decision process. The program then stores the results of the decision process so at any future time the set of spares by stock number and the detailed depot-level-repair program may be produced.

Shopping-list program. The output of the interactive budget-allocation program is subsequently operated on by a program called the shopping-list program, which uses the output from the interactive budget-allocation program to extract from the availability model the quantity of spares of each component that results from the decision process and the set of availability-versus-cost curves that were used as input to the interactive program. The shopping list program produces a worldwide stockage level for every recoverable component in the Air Force system.

The distribution model. The distribution model operates on the output of the shopping-list program and is designed to distribute the stock levels for all items among all bases and the depot so that the value of expected base-level backorders is minimized. The distribution model takes account of the worldwide distribution of aircraft by model-design-series and their collocation by base. It also explicitly models the cannibalization of shop-replaceable units from line-replaceable units.

The distribution model produces a file for every Air Force base that reflects all recoverable spares allocated to the base by stock number and quantity. Collectively, these files reflect the input budget originally allocated by the user of the interactive budget-allocation program. They also enable the user of the sortie-generation model to examine the sensitivity of the sortie-generation rate to alternative budget levels at any Air Force base for any tactical fighter aircraft for which a similar data base has been created by the maintenance subsystem. Currently, such aircraft include the A-10, F-4, F-15, F-16, and F-111.

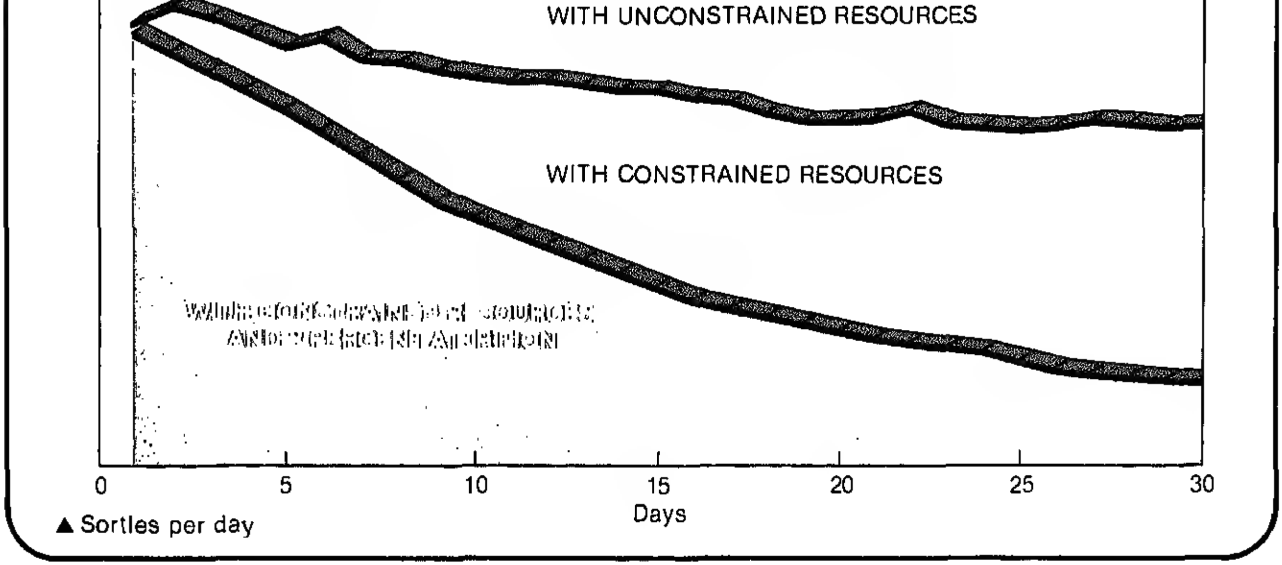
Notional bases. The notional base concept of the sortie-generation model is based on an approach that estimates the sortie-generation

Maintenance subsystem

The maintenance subsystem of the sortie-generation model translates maintenance actions that are recorded in the Air Force maintenance-data collection system into Air Force specialty codes that identify the specific skills of maintenance personnel by work center. This subsystem also translates unit manning documents into a number of authorized maintenance crews in each work center; estimates the number of jobs that the work center can perform simultaneously; determines the proportion of sorties that generate maintenance in each work center; and calculates the service rate for each center by considering the average number of jobs completed per hour by a crew.

The maintenance subsystem consists of two major sets of programs. The first consists of a software system called the common data extraction program, which was developed by the Air Force and modified by the Logistics Management Institute. This software accepts as input maintenance operating instructions and maintenance-history tapes from Air Force bases and the Air Force Program Document. The maintenance operating instructions reflect the work-center-to-AFSC relationships at the base; the maintenance history tapes contain six months' worth of maintenance data from each base. The Air Force Program Document shows the distribution of aircraft by model-design-series at all the bases. This set of programs produces an output tape that contains work-center-to-AFSC mappings along with maintenance-manhour and performance data.

The second major set of programs assimilates the output tape from the first set, data from the unit manning document, and the number of sorties flown during the same time period to which the maintenance history tape applies. The data file that is produced is entered into the sortie-generation model. This final data file is a remarkably distilled record of a myriad of data derived from a



work center, the data file contains the number of maintenance crews authorized, average crew size, service rate, manhour data, and the proportion of sorties flown that induce the need for corrective maintenance by each work center—the work-center break rate.

Applications and implications

The sortie-generation model system is useful for the assessment of resource levels in the planning, programming, and budgeting system. It can be used to understand better the effects of alternative resource levels on sortie-generation capability and can provide a better analytical basis for reports and testimony to Congress. The system can also assist in the development and evaluation of war-reserve materiel requirements and policies. Furthermore, it can be useful in the evaluation of the potential sortie-generation capability of new weapon systems when historical data inputs are replaced with postulated values.

Unfortunately, the sortie-generation model estimates maximal sortie-generation capability as a

engines and consumables. A shortfall of appropriate data in current Air Force data systems inhibits the system's extension to aerospace ground equipment, but, given such data, the sortie-generation model could indeed take explicit account of the effects of aerospace ground equipment.

Admittedly, the system operates at a tedious level of detail; however, it does allow a user or analyst to understand the effects of specific budget-allocation decisions on the measure of effectiveness. Of greater significance to DoD is the fact that the sortie-generation model system represents an approach that may be a workable one in estimating the resources-to-readiness relationship for a variety of resource categories, mission categories, and force types. DMJ

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Pressure to improve the overall readiness of aircraft weapon systems is being generated by the Congress and the Secretary of Defense. Increasingly, this pressure is being directed toward the obligation of funds to improve logistics support for all combat aircraft.

Specific congressional pressure has been levied through legislation and General Accounting Office audits. For example, the FY78 Defense Authorization Bill required DoD to submit a report to the Senate and House Armed Services Committees prescribing quantifiable and measurable material-readiness requirements for the armed services. The Pentagon was also required to inform these committees of subsequent changes in material-readiness needs and to provide appropriate written justification. Finally, DoD was told to estimate the effect of requested appropriations on material readiness in subsequent budget requests to the Congress.

Unfortunately, there is no established service approach to assessing weapon system readiness improvement candidates. As a response to this shortcoming, Department of Defense agencies have applied simulation techniques to the evaluation of proposed systems or policies affecting readiness. This technique is gaining wider acceptance as a potentially valuable tool to address problems for which current analytical approaches are either inadequate or too complex to perform.

Simulation modeling, which is basically Monte Carlo in nature, has been beneficial in Navy investigations ranging from air operations from a fixed air base or an aircraft carrier to assessing strategies for large-scale military battles. It has proven to be a relatively inexpensive, practical, and credible approach for relating, evaluating, and predicting the effect of implementing military system design and evolved into one of the leading analytic techniques in the field of operations research.

In the Navy, simulation modeling has focused on aviation. The Navy's Comprehensive Aircraft Support Effectiveness Evaluation model (CASEE) is a simulation approach that evaluates the complex interactions of system support status and the relationships that affect maintenance and support backlogs. In this regard, it is important to note that the pattern of failures and maintenance demands is as significant a driver of an aircraft's operations as is the ability of the support system to resupply spare parts or to provide trained maintainers.

CASEE has evolved over a period of 16 years of study and application under the sponsorship of the Naval Air Systems Command. In its present configuration, the model can be used to analyze the logistics support and operational relationships of one or more squadrons of carrier or shore-based aircraft. Additionally, the model is able to consider operational, developmental, or conceptual aircraft. This simulation model has been used to support sensitivity analyses for the F/A-18 program-management decisionmaking and logistics planning in equipment design, reliability and maintainability trade-offs, and logistic-support planning. Output from the model has been used as input to life-cycle cost analyses and as the basis for evaluating manpower-loading and spares-funding estimates.

CASEE is a discrete-event simulation model that relies on the random generation of events such as maintenance actions, spares demands, and downing discrepancies to initiate the simulation process. This approach promotes a less abstract and more faithful representation of the real system than is obtainable from analytical models. Although the

maintainability characteristics of the particular aircraft being simulated. Definition of the aircraft's components forms the majority of the model inputs, with the aircraft being defined at any reasonable level of detail desired. Normally, CASEE is exercised using inputs which define the aircraft down to the weapons-replaceable-assembly level. Based upon the development of comparability-studies data that relate projected characteristics to experience data for functional equivalent hardware already in existence, CASEE has also been utilized to evaluate conceptual aircraft alternatives.

The model's input categories are compatible with the Navy's aviation maintenance and material management reporting system. For each maintenance-significant, weapons-replaceable assembly, inputs include the probability of discovering a maintenance action either during inspection or inflight, the probability of a discrepancy causing a flight abort, and the probability of repair. Several operational and support-related inputs utilized to exercise the model include:

• The manpower loading for each organizational-level work center available, the number of

• The number of aircraft scheduled for launch, number of standby aircraft, and minimum number of aircraft required to avoid mission cancellation for each launch event.

• Turnaround, preflight, and daily inspection requirements, including elapsed time, manpower, and work center requirements.

• Phase or calendar maintenance requirements, including inspection interval, work center requirements, manpower, average elapsed time, minimum inspection time, and flight check requirements for each inspection.

• Aircraft ordnance loading requirements by mission type, and work center, manpower, and average elapsed time to accomplish the ordnance loading.

• Mission-essential subsystems by mission type.

• A cannibalization policy.

A simulation model such as CASEE provides the capability to estimate readiness and mission-capability-level achievements for a weapon system in an operating environment under specific resource constraints. Varying the level of resources will result in a calculated change in the achieved readiness level. One such relationship that assumes

Figure 1. The impact of the spares level on mission capability during peacetime operations

The curve depicted here represents the results of four CASEE simulations, where system reliability was held constant while the level of available spares increased.

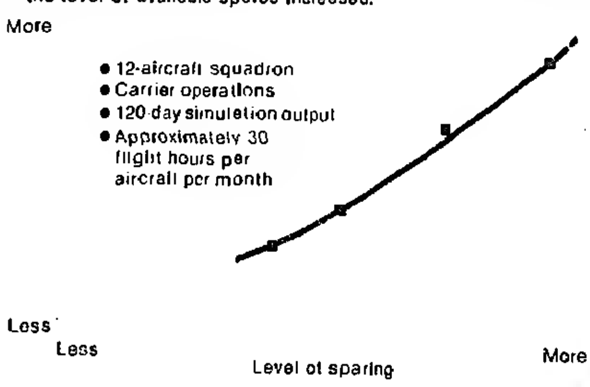
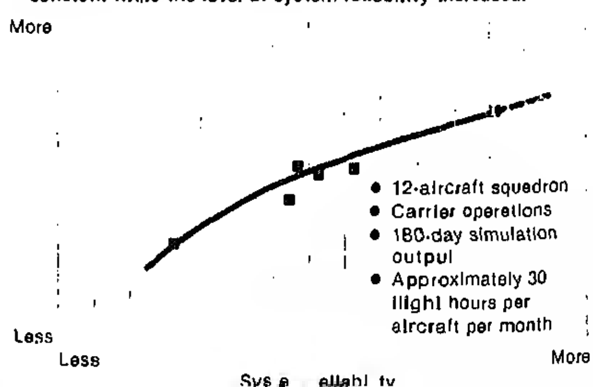


Figure 2. The impact of system reliability on mission capability during peacetime operations

The curve depicted here represents the results of six CASEE simulations, where logistics support resources were held constant while the level of system reliability increased.



yield an explicit solution, it is useful for sensitivity analyses.

a fixed system design and varies only the level of spares available to the operational squadron is illustrated in Figure 1. The scatter of points is typical of the *monte carlo* process. Figure 2 displays estimates of the impact on mission capability of changing system reliability where logistics support resources are held fixed. This demonstrates a current problem of logistic support planning—provisioning governed by budgets which are fixed early in a program, before the system develops demand experience, or before it achieves its predicted reliability level.

The CASEE model is particularly useful because it provides explicit visibility of resource inputs and status. The ability to examine the workload backlog due to manpower constraints or spares shortages allows an analyst to estimate the impact of changing manpower or spares levels. The analyst can account for the necessary level of resources and estimate the marginal costs of changing mission capability levels.

Analyses that are used to develop readiness relationships may never be reduced to simple procedures. They are inherently complex and depend on analyses of the queues or prioritized line-ups that accumulate as a result of maintenance demands of aircraft systems.

In this context, simulation-based analysis is an engineer's and logistician's tool that can be tailored for design trade-off studies and logistics and budget planning. The results generated by this microanalysis technique require careful consideration before they can be accepted as credible inputs to the overall process that includes the program planning and budgeting system. Because a simulation model does not yield an explicit solution, the importance of technical review of simulation outputs cannot be overem hasized. Therefore, any effort to apply a simulation model must also include an independent review of the validity of the solution.

Any analyses using a simulation model require a detailed examination of specific run parameters to establish whether the outcome of the simulation events are explainable and technically consistent. This can be performed by examining and correlating selected parameters with real-world data to determine whether the generated results are behaving in a rational and realistic manner within the statistical bounds of anticipated results. The degree and extent of this effort will vary depending on the type of analysis. Other factors such as the length of the simulation period, the number of required runs, and the type of statistical procedure that should be applied must be defined to assure technically accurate and representative results.

When properly applied, simulation modeling and techniques can play an increasingly important role in a program's design and acquisition process and can be particularly useful in evaluating the levels of logistic support and budget planning that will reinforce the readiness objectives of a system in accordance with defense needs. DMJ

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A task-based approach to soldier training

The skill qualification test program is proving valuable as a training-evaluation and personnel-management tool.

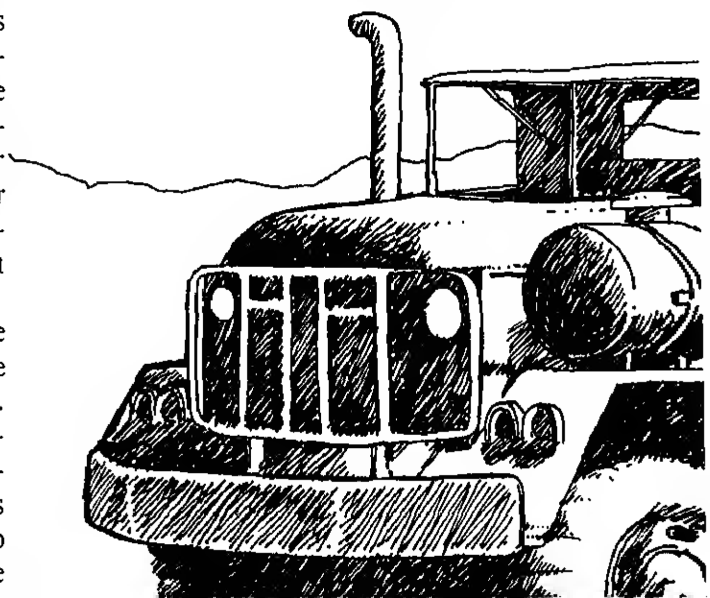
Since being introduced four years ago, the skill qualification test (SQT) program has markedly improved individual training and military-personnel management in the Army. Skill qualification tests differ from conventional personnel tests in construction and interpretation. Conventional tests are designed to compare individuals with one another and are categorized as norm-based. SQTs are designed to measure performance against specific objectives. They are categorized as task-based. For each of the performance objectives that define a task, a soldier earns a *Go* or a *No-Go* score. *Go* means the soldier has met the performance standard for a task. *No-Go* means the soldier needs more training on that task.

Standards of performance exist for each of the tasks, which collectively form a skill. Soldiers are told what the standards are before the test is given. Each soldier is issued a soldier's manual that describes the task standards for his particular military occupational specialty. Roughly 60 days before annual testing, soldiers are notified as to which tasks in the soldier's manual they will be

Training system development

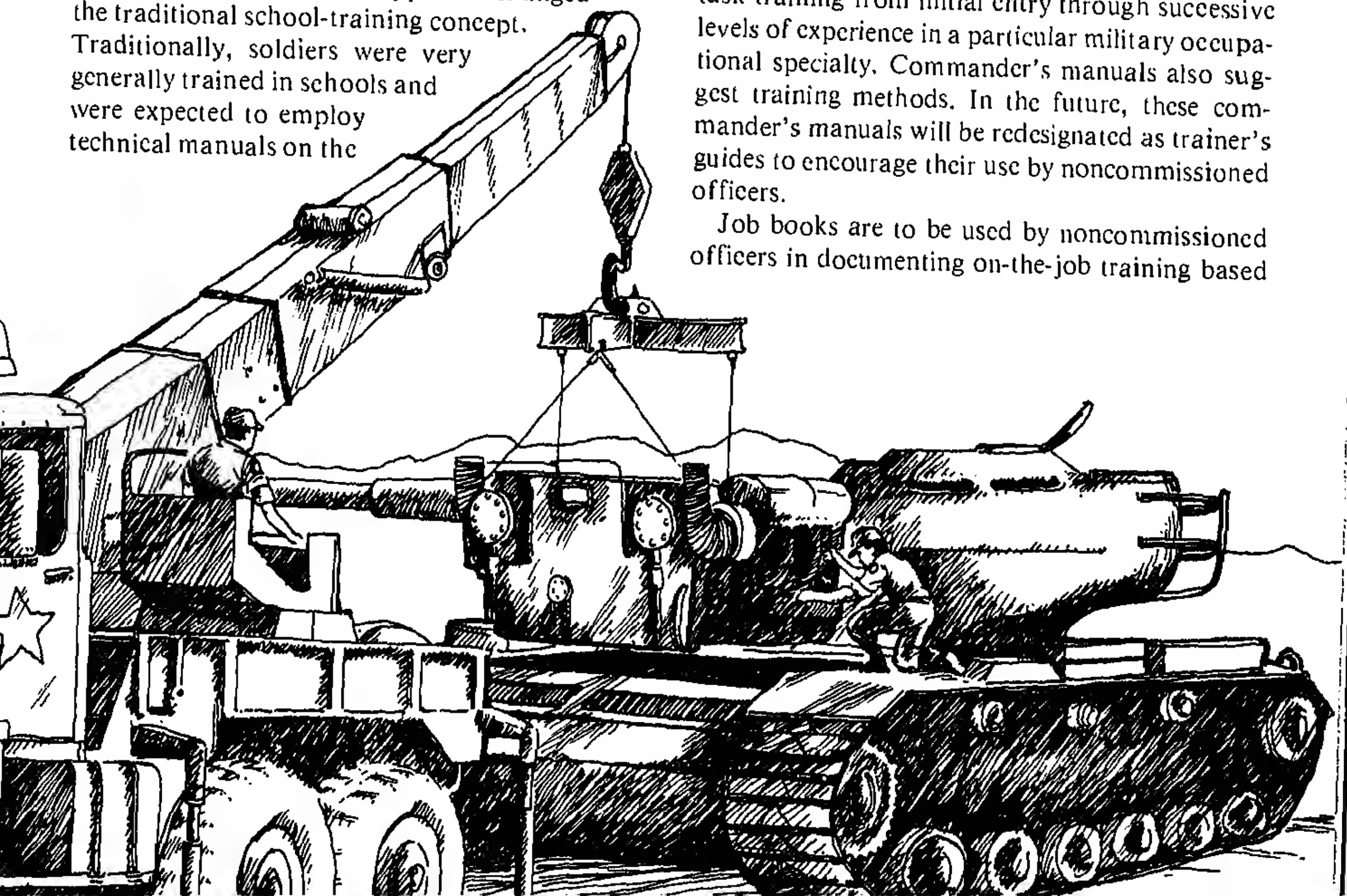
The U.S. Army Research Institute for the Behavioral and Social Sciences has participated in the development of the SQT program since its beginning in 1975 as part of a plan to modernize and decentralize Army training. The U.S. Army Training and Doctrine Command (TRADOC) sought to take a systems approach. Instructional Systems Design concepts were used to produce a series of training materials to support performance-oriented, task-based training. This training development begins with job and task analysis to identify specific objectives. This makes it possible to show soldiers what tasks they must perform, under what conditions they must perform them, and what performance standards must be met. The objectives clearly state how well the task must be done to meet requirements. Soldiers are then tested, trained, and retested until they can meet requirements.

This highly specific approach demanded that lengthy task lists be reduced to include only the cri-



threat, organization, and weapon systems were examined. Unit requirements were critical. Hard decisions were made about where and when to provide training in each critical task. Initial entry training was restricted to very common soldier tasks. Entry-level occupational specialty training focused on tasks and duty positions to which new soldiers were commonly and immediately assigned. Certain tasks that required specific equipment were deliberately planned for unit training. Switchboard operators, for instance, might find any of several kinds of switchboards in their units; consequently, specific switchboard training was assigned to the units.

The task-based systems approach changed the traditional school-training concept. Traditionally, soldiers were very generally trained in schools and were expected to employ technical manuals on the



systems approach, units train their own troops for military occupational specialty duty positions. To make decentralized training possible and efficient, TRADOC supplied Army units with a series of tools for individual and collective training. The major tools for individual training are soldier's manuals, commander's manuals, job books, training extension course lessons, and skill qualification tests (SQT).

The soldier's manuals describe the critical tasks, performance conditions, and standards for each military occupational specialty skill level. These manuals also reference training extension course lessons and other training materials.

Commander's manuals indicate the sequence of task training from initial entry through successive levels of experience in a particular military occupational specialty. Commander's manuals also suggest training methods. In the future, these commander's manuals will be redesignated as trainer's guides to encourage their use by noncommissioned officers.

Job books are to be used by noncommissioned officers in documenting on-the-job training based

mode. These lessons offer performance-oriented training, programmed tests, and immediate feedback. Lesson performance, when properly supervised and recorded in the job books, may serve as a record of accomplishment.

Skill qualification tests are task-based training-evaluation tools. They are designed to drive individual training through the administrative devices of mandatory annual testing and assimilation of results by personnel management. Task-based feedback to commanders is intended to improve training management in the field.

Components of SQT

The first step in gathering skill qualification test data on soldiers is to obtain the performance data contained in the job books and in other unit records. This is called the job-site component of the SQT. It consists of physical-training tests results and qualifications to use certain weapons and of the ability to perform certain tasks that cannot be formally tested on a scheduled basis.

The second part of the SQT is the hands-on component. This component is a series of standardized individual field-performance tests covering common tasks in battlefield survival, first aid, weapon usage, and specific duty tasks taken from the soldier's manual.

The administration of the hands-on component is well standardized. For a high-density military occupational specialty like infantry, the spoken instructions are tape-recorded so that instructors can give their undivided attention to observing and recording performance. Each solider is given immediate feedback on his performance. To reduce fear of testing, instructors take the soldiers through a dry run before giving the hands-on component for record. The percentages of soldiers scoring *Go* on the hands-on component and on the job-site tasks generally have been high.

The third and most difficult part of the SQT is the skill component. The skill component is a

so that the answers are clearly essential to duty performance. This is not to say that performance on the skill component is the same as actual performance. However, most skill component questions appear to measure knowledge that is critical to proper field performance.

For example, the knowledge necessary to destroy an enemy mine when one is not under direct observation by the enemy consists of knowing how to make it explode either by using a grapnel and line or by exploding a small charge on pressure-sensitive mines. Safety precautions involve distance, cover, and time. Correct answers to five or six skill-component items seem to be a reasonable basis for assuming that a soldier could destroy a real mine, thus obviating the need to resort to actual or simulated field testing. Yet this particular skill-component task has yielded low percentages of *Go* scores among infantrymen for several years. Any remedial training effects on this task may be obscured among the large numbers of soldiers scoring *No-Go* for the first time each year. However, another reason for low scores may be that trainers think a soldier only has to read the SQT notice and study the soldier's manual to prepare for the skill component. Preparation to take the skill component may often be a do-it-yourself project.

Preparing for skill component

Research suggests that many soldiers must be led into active reading before they will learn and retain the information in the soldier's manual. Some form of programmed study is needed. Research also suggests that if the skill component for record were preceded by a dry run with immediate feedback, as is done with the hands-on component, skill-component performances would improve.

At the higher levels of combat military occupational specialties, the number of skill-component tasks and the importance of skill-com onent per-

their careers, sergeants and technicians are expected to prepare on their own for their skill qualification tests. It does appear, however, that some form of guided study or diagnostic pretesting would be beneficial to those senior soldiers.

There has been considerable puzzlement in the education and training field as to when it is proper to teach the test and when it is not. The answer seems to depend on the meaning that can be attached to a task-based test score. If the operational definition of a task-based test, complete with conditions and standards, is accurate and admits to little or no variation in task practice, then the teaching of the test as an end in itself is proper. In that context, a test becomes the same as a terminal training objective. For such a test, the development of alternative test forms would prove very difficult unless the forms differed only trivially. There would be little else to know or do. Performance in excess of the operational standard would seem pointless. Conditions other than those presented would seem irrelevant or too easily understood by the performer. Some SQT tasks are like that.

On the other hand, if a task contained in a soldier's manual admits wide practical variations in conditions, execution, or desirable performance standards, then the teaching of the test would be wrong except as a starting point or intermediate training objective. One correct performance cannot be taken as evidence of correct performance in a class of performances. For example, a knowledge of map reading cannot be inferred from a soldier's knowledge of a few pretested map symbols. Yet learning a few symbols in this way may serve as a useful beginning in map reading.

Training process

In training, it is often useful to teach the test; however, it is important to be aware of the limitations of any one test. For personnel management, fairness requires that all soldiers have the same

measurable by single specific tasks. The test-train-retest model in practice moves from one specific task to another in a generally progressive fashion. Variations in conditions are explored and standards are pushed upward. Retraining is used against forgetting. The entire process is reactive. Trainer and trainees learn from rapid feedback. Irrelevant and awkward approaches are dropped. Previously mastered smaller tasks are integrated into larger tasks.

The kind of process is common on athletic fields, in laboratories, and in many workshops. Coaches, teachers, and trainers have long used such a process. For some time now, Army trainers have grappled with the question of how to make this process work in the Army on a large scale.

Instructional systems design suggests that this process can be managed as a self-correcting, progressive network of feedback loops. Specificity is essential to progressive improvements in performance and to the training system itself. Experience with the system changes the specifications. The whole-systems approach represented in soldier's manuals and skill qualification tests is early in the evolutionary development toward excellence on a large scale. However, the specificity of the system can be seriously misunderstood. In particular, the use of SQT scores in personnel management may lead many soldiers and noncommissioned officers to treat the test tasks as terminal training objectives—as ends in themselves, if you will.

The secondary function of skill qualification tests is improvement of personnel management. The fact that SQT scores are used in personnel-management and promotion decisions tends to motivate soldiers to prepare for the test. In this context, the SQT total scores are directly analogous to conventional norm-based test scores. Such scores take their meaning from the relative performances of individuals in norm groups considered for promotions, assignments, or other personnel action. Percentile points may be computed to assist personnel action boards in deciding how

is only one factor in personnel decisions, but it does have significant impact.

The U.S. Army Training and Doctrine Command recognizes that tasks included in any given skill qualification test are selected samples of tasks in soldier's manuals and that SQT standards are often practical testing levels as contrasted with high standards of competitive excellence. To soldiers and their sergeants scheduled for record SQT administration, however, these limits on the meaning of SQT performance are likely to seem quite academic. Beating the test and competing with others on the test are the immediate concerns of a soldier taking a skill qualification test.

In the minds of the soldiers, the tested tasks may indeed be the real goals. Unfortunately, the present construction of SQTs does not present the opportunity for or demand the demonstration of excellence. Different kinds of tasks are tested once against a practical minimum standard of performance. This type of construction provides a fairly wide sampling of different tasks, but it does not provide for the kind of progressive capability normally associated with high degrees of skill. Meeting the standards for a variety of tasks at the level of intermediate training objectives is highly desirable, but it does not equate to competitive excellence in any one of them.

Training to higher standards

If task-based training is to deliver the kind of competitive excellence on the battlefield that TRADOC envisioned, then it must go beyond the level of presenting intermediate training objectives as goals. We believe this may be approached by developing small progressive sequences of task-based training modules in close collaboration with the Noncommissioned Officer Education System. Sergeants will have to do it to believe it, and they will need to document the real-time requirements.

This approach is considered a logical and necessar ne step the evol ution of skil qualif'catio

Institute for the Behavioral and Social Sciences on the measurement characteristics and interpretation of SQT scores is expected to promote continued development of task-based training-evaluation methods.

Meanwhile, the interpretation of SQT results on a task-by-task basis requires detailed knowledge of the test materials, the military tasks actually performed in the day-to-day line of duty, and the soldier's training or preparation for the test. TRADOC provides feedback to commanders with the expectation that they will be able to judge the meaning of task-by-task results in the context of their unit experience and requirements.

Diagnostic use of SQT results for making training-management decisions requires professional judgment by commanders, training managers, and trainers. They all must be fully familiar with the territory. The temptation to use SQT results without considerable knowledge of the operational environment and to aggregate such results to develop a broad portrait of soldier performance should be strongly resisted. There are too many variations among SQT tasks and these are complicated by differences between doctrinal intent and field practice.

Now in an intermediate state of development, the SQT system is a sound technique for improving individual training and, ultimately, combat readiness. SQT results can be used within Army units to manage training in the context of the specific task standards for troop duties and training. DMJ

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in weapon system acquisition

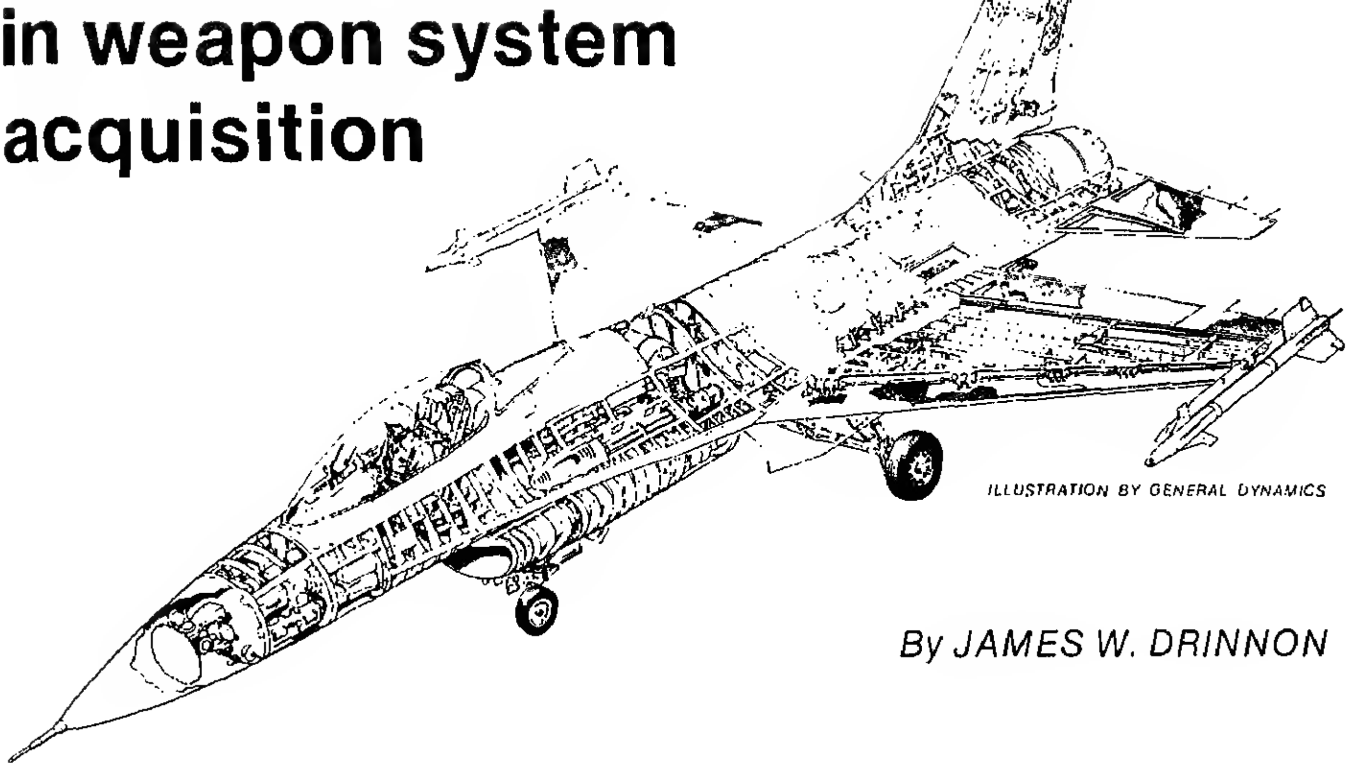
ILLUSTRATION BY GENERAL DYNAMICS

By JAMES W. DRINNON

A firm may operate on a more efficient learning curve under competitive conditions than under sole-source conditions.

Considerable analytical and empirical work has been undertaken in recent years to develop a foundation for evaluating the effectiveness of competition in weapon system acquisition. As one might expect, the sophistication of this effort has steadily evolved.

Originally, analysts compared a price obtained competitively with the price of a preceding sole-source buy; any price reduction was attributed to competitive forces. Subsequently, analysts determined that regardless of competitive pressures, a portion of the price reduction was attributable to production efficiencies achieved by an increasingly experienced sole-source producer. More recently, of either continuously improving manufacturing efficiencies or one-time price reductions.

Despite the advances of these analytical efforts over time, many obstacles impede progress. One major hindrance is that competition may be applied in many forms and in various phases of the acquisition cycle. The numerous details specific to these forms make theoretical specification of competition highly complex. It is also difficult to construct an empirical data base. Such a base must rely on subjective judgments on numerous details of a program. This difficulty is compounded when a program history cannot be fully reconstructed. In fact, so many elements enter into the outcome

can be explained by technical problems, person-alities, organizational structures, and budget issues, as well as by introduction of competition. Therefore, an empirical approach to quantifying the effectiveness of competition remains obstructed.

However, recent work by the Army Procurement Research Office, by the Institute for Defense Analyses, and by the author in an earlier study has helped to clarify what is known about production competition. These efforts have provided a clearer and less complex theoretical framework which may be applied in a variety of contexts.[1]

Although the absence of a reliable data base is a drawback, the framework allows sensitivity testing of important parameters. Furthermore, the analytical structure indicates what type of empirical approach is required to make further progress. Finally, one important finding has emerged: since competition appears to affect a firm's rate of learning, the expected percentage savings in a program depends critically on the number of units produced. A firm's learning curve not only shifts downward when competition is introduced, it also steepens at that point. The extent of the curve's steepening and the point at which competition is introduced directly affect the estimated percentage savings. The implication is that no single number represents the potential percentage savings from competition but that a series of estimated savings percentages must be determined for various levels of production.

The analytical structure is best explained in graphical form, based on the idea of the learning curve. The learning curve can be defined as the relationship between price and quantity which indi-

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[1] *Three recent studies regarding the effects of production competition are:*

E. T. Lovett and M. G. Norton, Determining and Forecasting Savings from Competing Previously Sole Source-Noncompetitive Contracts, *Army Procurement Research Office, October 1978.*

G. G. Daly, H. P. Gates, and J. A. Schuttinga, The Effect of Price Competition on Weapon System Acquisition Costs,

by various names and is supported by the
and empirical studies,[2] the point is simply th
a relationship is assumed to hold. It is ge
thought that the introduction of competitio
to a price reduction, and possibly to cos
tion, based on competitive pressures for
tion efficiency.

Until recently, the usual model of this p
duction would assume a parallel downward
the learning curve, which means each u
duced under competitive procurement exp
the same percentage reduction in price a
This movement is depicted in the left grap
Figure. Under sole-source conditions, a fi
duces from point A to point B and wou
continued to point C without the introduc
competition. However, at point B, the fi
forced into a price competition and had t
its price to point D to win the contract. T
now continues to point E. Although the re
could have been the result of lower profi
cost efficiencies, the result is the same to
curer. The total savings is the sum represe
the area in BCED. The percentage saving
same area BCED divided by the total are
the line BC. That percentage is constant
program and may be applied to any quantit
the program office wishes to procure. A
associated with the introduction of a secon
must be netted out.

But an adjustment may be made to accou
rotation in the learning curve. This
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curve under competitive conditions tha
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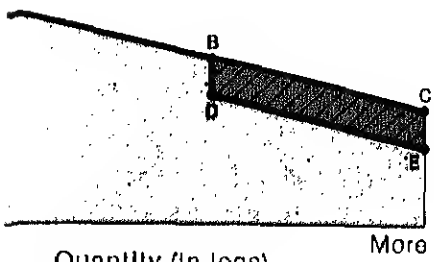
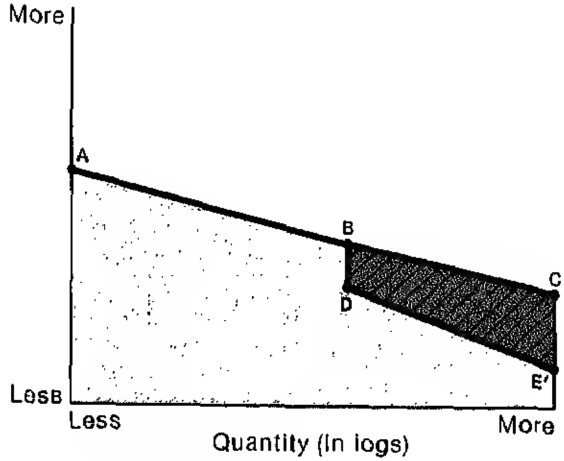
BC.

It is important to note that the percen
savings, as well as the do l r vo l o

quantities can cause different savings rates.





ent savings, a similar or virtually n should result in a similar rate. ction quantities are sufficient to savings rates. Empirical measures inapplicable since they do not re- The savings on the final unit at to be greater than the savings on point D. Therefore, any projec- on of competition must consider antities through the shift and the arning curve.

aple framework is established, s can be based on learning rates, costs associated with multiple portant to note that no adequate —nor is it clear that one will be hich will allow statistical estima- portant model parameters as the hanges of the curves.

he model is that "what if" ques- essed. Moreover, sensitivities can ependent of precise estimates for to determine specifically which

competition or the problems associated with international cooperation on a program. Such cooperation requires estimates of price impacts caused by international transfer problems, exchange rates, and so forth. Nonetheless, a basic framework exists which may be developed in a variety of directions and which will allow sensitivity testing of key assumptions. It is not premature to consider how further progress may be made. DMJ

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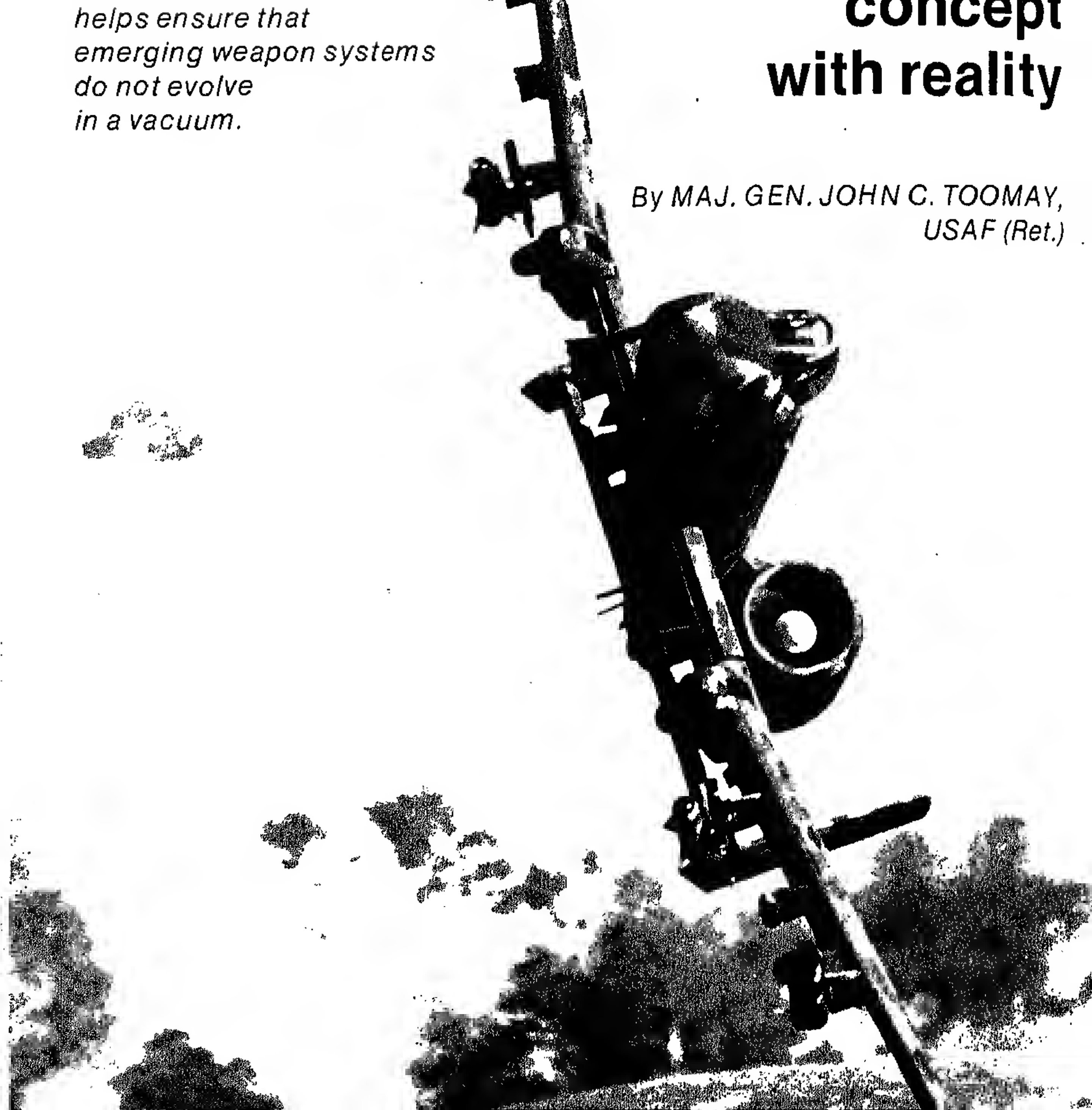
be- lle, he to ex- ted ex- ry, ex- tic tu- lar ler ci- ng, he he cy aff est he he ere ial on o- iat ve na its c- ry r- ir nd en f- e- ne

helps ensure that
emerging weapon systems
do not evolve
in a vacuum.

concept
with reality

By MAJ. GEN. JOHN C. TOOMAY,
USAF (Ret.)



these commanders addressed *logic packages* of planning. Beginning in the early 1960s, though, substantive changes were made in the planning process. Nonetheless, the perception remained that planning at the command was not all it should or could be.

Unlike their predecessors, former AFSC commander, General Alton D. Slay, and current AFSC commander, General Robert T. Marsh, have chosen to address all planning as a single entity. Out of this approach has come a comprehensive set of initiatives, including development planning, program planning, and corporate planning. Corporate planning is being handled as a related but separable entity. However, development planning and program planning, with all their associated problems and complexities, have been taken on in toto. The result is a completely remodeled planning process at the Air Force Systems Command. The effort by which this restructuring was accomplished was called Project VANGUARD, and the resulting, currently operative process retains the name VANGUARD.

The new perspective on planning offered by Project VANGUARD was obtained in three steps. These steps consisted of a critique of current planning to identify concerns, a return to fundamentals to establish a solid underlying rationale for planning, and an implementation that adhered to that rationale and that contained all needed revisions of existing policies and procedures to accommodate the new process.

The critique of the traditional planning process highlighted problems endemic to most tax-supported organizations that have no profit-and-loss statement to serve as a feedback loop. One could cynically view weapon-systems planning as an interaction among the user, the technologist, the bureaucrat, the developer, and the planner.

The user is pictured as demanding more than he needs and as having strong operational biases. The technologist promises more than he can reasonably

gins, is blind to all factors except cost, schedule, and performance in his contract with DoD. The planner is viewed as having no role other than to arrange the meeting and invite the others.

While these characterizations are somewhat exaggerated, most individuals who are experienced in military research and development can cite examples of each. The Manned Orbiting Laboratory, Dynasoar, and Aerospace Plane are good examples of the symbiosis of the over-optimistic technologist and the insatiable user. Unfortunately, even in the wake of these and similar miscues among the dominant players, the planner remained a nonentity.

No doubt, the turbulence among the five principals gave birth to the *advocacy theory* of planning, which was prevalent in AFSC for many years. The approach was that of devising and revising the program to appeal to an influential constituency that included a partisan supporter on the Air Staff and the OSD Staff and somebody at the highest possible level who would strongly embrace the program. Such endorsements emanated from the top down so that requirements documents were written after the fact. In other words, the formal operational problem appeared after the solution was invented. Indeed, a suprising number of programs have arisen this way. However, the fact that many of these systems are very useful and have received accolades does not expunge the stigma associated with their origins.

This kind of activity brings the requirements process itself into question. In the idealized process, the user states a need for a defined military capability, the developer proposes technical alternatives for achieving that capability, and the Air Staff makes the decision on the feasibility and appropriateness of the proposed alternatives. Even when idealized, this approach is not without difficulties. One must ask whether there is really a requirement, or just a *desirement,* and whether the required equipment will interact with all the other

cluding a penchant for getting into the user's and developer's business. The Air Staff has never practiced or fully endorsed the principle that there are appropriate as well as inappropriate responsibilities and tasks for each level in a hierarchy. An intricate and long-standing bureaucratic maze stultifies the requirements process. It is not so surprising that many of our weapons systems have materialized without official requirements. Interestingly, a weapon system may be approved based on a particular required military capability without due consideration given to other missions which it might or might not be able to perform.

In the near future, during the F-4 aircraft phaseout, the tactical Air Force will predominantly consist of single-seat aircraft—the F-15, F-16, and A-10. Yet it is not known whether technology will permit the demanding air-to-ground missions of the 1980s to be performed by a single-seat airplane. The implication is that planning for fighter aircraft was done with a case-by-case approach rather than with an integrated approach that addressed the needs of the whole tactical arena.

The tendency to satisfy one need with one system often equates to a failure to synthesize needs and systems. This pitfall is called the *point-solution syndrome.* Imaginative scientists, engineers, and some administrators enjoy formulating and offering possible solutions to problems, and there are always plenty of unsolicited proposals from industry. If these imaginative people are in positions of influence, their point-solutions often become *show-cause* issues for the services, which must either prove the solution inappropriate or proceed with its development.

While lack of macro-planning can be calamitous, lack of micro-planning can be wasteful in terms of resources and time. The component parts of a modern weapon system must dovetail properly or efficiency is lost. Thus, the avionics, the engines, the airframe, and all the associated equipment must be blended carefull and completely.

complete consideration of these black boxes and their integration. Integrating the Joint Tactical Information Distribution System and NAVSTAR, a space-based navigation system, into the F-16 will be extremely difficult. A new display may be required to accommodate all the information system's data in the F-15, whose flight-control system is unsuited to the installation of terrain-following and terrain-avoidance equipment. The F-111 crew capsule cannot accommodate one more subsystem within its confines without a complete requalification. Some of these and similar situations stem from occurrences that are not foreseeable during development; other situations are simply manifestations of inadequate planning.

Integration with real world

There is also great concern about relevance and emphasis, both of which have been addressed for years, particularly by the service laboratories. Nonetheless, abuses remain, and perpetual vigilance is essential. It is extremely difficult to assess relevance when the avowed purpose of exploratory development is to allow the assessment of the broadest practicable set of technical alternatives to meet generic needs. Similarly, it is extremely difficult to judge emphasis when the laboratories are directed to make contributions to systems and to be comprehensive in scope to the point of actually manually building black boxes for systems use. The solution does not lie in subjective judgment alone; clearly, a set of planning principles is needed for judicious resolution of these issues.

The final concern is for the efficacy of planning. There is a tendency for planning to be introspective and self-serving. This happens when planning is organized without forced interaction with real-world program or when the interaction is so generic or so abstract that it can remain casual and philosophical. There is a natural tension between the planner—who tends to idealize the world, theorize, and mani ulate conce ts rather than

planning initiative and result in the old situation which was characterized by spurts of intense planning activities—a planning-by-exception mode, if you will. Boiled down to their essence, all of these concerns could be expressed in three statements:

- The arbitrary and capricious *advocacy* approach to planning is unacceptable.
- The Air Force and its systems are so complex that planning for single systems and subsystems is no longer practicable, and a system-of-systems approach is mandatory.
- A planning initiative, no matter how brilliant, has no chance of working without a prevailing discipline that demands relevance and sustained interaction with the real world.

The diverse nature of these planning problems calls for a comprehensive and integrated approach to a solution. Planning has been said to be nothing more than *a rational approach to objectives;* thus it is possible to develop integrated planning by building it up from first principles. This is the philosophy anchored in VANGUARD. However, it should be noted that many other planning philosophies have been built up in the same way, and it would be a mistake to assume that new planning concepts would arise from this approach. Nonetheless, an integrated, comprehensive, and complete planning structure should be obtainable.

The planning process, regardless of the application, has three parts: analysis, synthesis, and implementation. The analysis portion breaks the problem up into digestible logic chunks and employs quantitative methods to uncover critical relationships and driving functions, makes comparisons, and determines proper courses of action. The subsets of all the logic chunks must make up the universal set of all Air Force missions, everything must be covered. Each chunk must be mutually exclusive so that there is no confusion or overlap. In the synthesis portion, the logic chunks are melded into a rational, cohesive whole. Subjective or objective methods are used to reconcile the logic

terminate hostilities under conditions favorable to the United States. Within those broad objectives, the Air Force has been assigned particular missions, involving both strategic and tactical roles. The task of accomplishing these missions determines what kind of an Air Force is needed. Thus, the Air Force is not an entity that merely has so many bases, airplanes and people. It is an entity that has defined military capabilities. All its other characteristics like bases, airplanes, and people are derived from the required capabilities. A planner must realize and accept that the form of the Air Force should be molded by its functions, not the reverse.

Missions tend to fall into several large logic packages, called mission areas. These can vary, depending on a chosen logic structure, convenience, or edicts from above. There is no *right* way to encompass these missions; the important thing is for the list to be exhaustive because it will bound Air Force planning. A customary set of mission areas includes:

- Strategic.
- Tactical.
- Reconnaissance.
- Command, control, and communications.
- Defense-wide systems.
- Management and support.
- Technology base.

For VANGUARD, strategic is broken into strategic offense and strategic defense, and tactical into air-to-surface and counter air. Intelligence is part of reconnaissance; mobility, and launch and orbital support are shredded out from defense-wide systems.

The broadness of these missions makes it difficult to do the kind of analyses needed for good planning, particularly for planning of systems and systems-of-systems. The missions need to be dissected into functions and tasks and even into elements and subelements. At some level of specificity, analysis becomes practicable.

sufficient analysis tools, studies, policy guidance, and conventional wisdom exist to facilitate them. The third step, prioritization, is very difficult, but even it is tractable. In the strategic area, the balance between weapons deliverable into the Soviet Union and weapons deliverable against us by the Soviet Union is a crucial facet of deterrence. Each deficiency can be weighed by its incremental effect on that balance.

In the tactical arena, there are several quantitative measures available. One is the number of enemy armored fighting vehicles that must be eliminated in a given time. Again, the deficiencies can be weighed in terms of their incremental effect. Interestingly, in both strategic and tactical areas, incremental effects can be calculated even for factors not directly coupled to the measure of effectiveness. A tactical intelligence-fusion system that substantially reduces targeting time or a warning system that adds precious seconds to the available response time can be evaluated because they change the rate of target kills.

Analysis to synthesis

The prioritized deficiencies are directly convertible into development goals by turning the negative statement of deficiencies into the positive language of goals. The derivation of development goals completes the analysis. The next step is one of synthesis—the aggregation of a set of programs that will redress the deficiencies and provide the required capability against the postulated threat as early as practicable and at minimum cost. This synthesis process embraces many variables and subjective factors. There are several logic frameworks to work within. These frameworks are self-consistent but cannot be made cross-consistent. This means that the synthesis process must be forever imperfect. Nonetheless, it can still be very useful.

In VANGUARD, the synthesis is a two-step process. First, all the efforts postulated for the technical alternatives for eliminating the deficiencies that will exist even if the baseline plan is executed. The plan that results from the synthesis constitutes the proposed plan.

The way in which these deficiencies are redressed depends on the deficiency's nature, its priority, the anticipated program cost, and the availability of technology. The status of technology tends to dictate the form of the correcting effort, whether in explanatory, advanced, or engineering development. It also dictates the time required to correct the deficiency. Except in national emergencies, more than ten years is needed to go from initiation of acquisition with the milestone zero decision to a fielded system. Thus, a plan that corrects all deficiencies may extend 15 years or more into the future. Sometimes the necessary technology is simply not available. In this case, the plan proposes technology efforts. In fact, the investment strategy of the Air Force laboratories is based substantially on the development goals derived from VANGUARD analyses.

The analysis-synthesis process offers in-depth analysis of mission areas, baseline plans showing how the Air Force will fare if the current program is carried out, and proposals that indicate how, when, and for how much, deficiencies can be corrected. But these plans are incomplete in two ways. They provide no means for efficient planning of systems, subsystems, and components across mission areas. Moreover, they do not provide a means for doing the marginal analysis that will allow good decisionmaking across mission areas.

Mission-area plans that simply specify all the equipment required can result in extravagance in undisciplined system acquisition. Mission-area efforts, which constitute a vertical integration to accomplish a mission, must be reconciled with their respective functional areas, which constitute a horizontal integration of a particular discipline across mission-area lines. That this sort of discipline has been lacking in the past is evidenced by the presence of 26 different inertial navigation

ciplined to achieve optimum commonality, standardization, and acquisition procedural efficiency over time for all avionics. Correspondingly, there are electronic-warfare and propulsion master plans that accomplish the same objectives in those fields. Other functional-area plans can be added as needed to keep the functional areas orderly and efficient.

For a complete planning perspective across mission areas, a cut in one other dimension is required. Quality and quantity of forces are inseparable. Force-structure levels are inevitably affected by the quality of individual elements. The operational readiness of the forces depends on the extent and scheduling of modification programs. Of course, there are acknowledged political and diplomatic aspects to force structure that transcend the processes discussed here. In the world of good planning, however, force-on-force estimates are requisite to cost-effectiveness and force-status analyses that allow comparisons of alternative ways of accomplishing the same objectives. Therefore, force-element plans, along with the mission-area plans and functional plans, are required for a complete statement.

In VANGUARD, the complete set of plans includes 7 mission-area and 17 sub-mission area plans, 9 functional-area plans, and 3 force-element plans, for a total of 36 plans (see Figure 1). Taken together, the mission-area plans represent the complete Air Force mission. However, the functional and force-element plans are not an exhaustive set. They are called out when needed to address concerns.

- Strategic offense
- Strategic defense
  - Atmospheric surveillance and warning
  - Atmospheric threat engagement
  - Ballistic missile surveillance and warning
  - Space defense
- Counter air
  - Offensive counter air
  - Defensive counter air
  - Command and control countermeasures
- Air-to-surface
  - Defense suppression
  - Fixed and non-fixed targets
- Airlift
  - Intertheater airlift
  - Intratheater airlift
  - Support airlift
- Reconnaissance
  - Reconnaissance
  - Surveillance
  - Correlation-fusion
- Command, control, communication
  - Strategic C^3
  - Tactical C^3
  - Support C^3

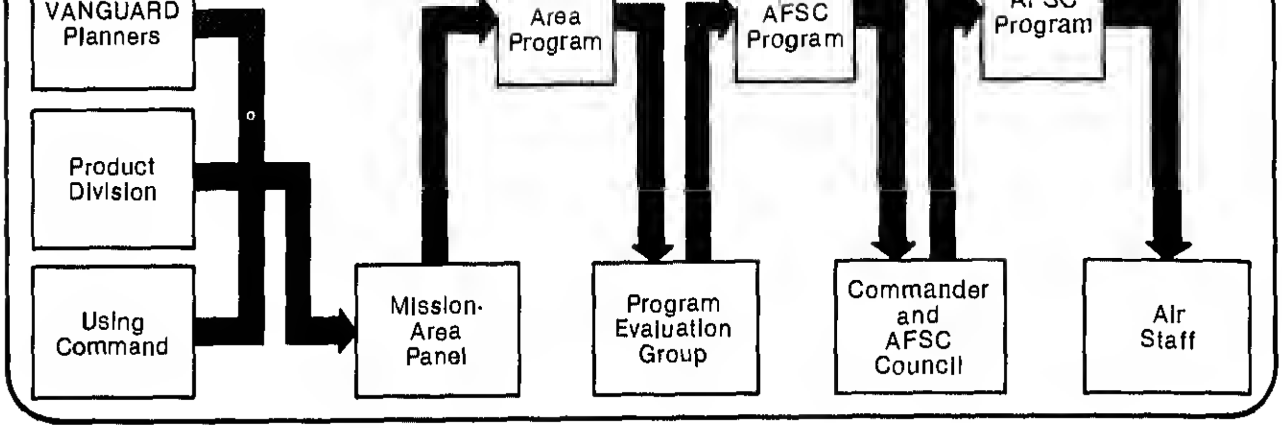
Functional
- Propulsion
- Avionics
- Nuclear munitions
- Space
- Armament
- Remotely piloted vehicles and drones
- Electronic warfare
- Computer resources
- Technology base

Force Element
- Air breathing force
- Intercontinental ballistic missiles
- Fighter aircraft and fighter bombers

Corporate resource allocation

As noted previously, trade-offs across mission areas are extremely difficult. Methods for allocating resources on a completely quantitative basis had been sought long before it was noted that much of what we call quantitative today was methods have been examined for VANGUARD but found wanting. Instead, a modified Delphi approach is used in the VANGUARD process to do trade-offs across mission areas and, in some cases,

[1] *David W. Miller and Martin K. Starr,* The Structure of Human Decision, *Englewood Cliffs, N.J.: Prentice-Hall Inc.,*



to modify planning within mission areas.

Three levels of expert opinion and judgment are applied (see Figure 2). The proposed program is formulated using input from the VANGUARD planners, the product-divisions, and the Mission-Area Panels of the Program Evaluation Group. The using command also participates in the effort. The first level of review of the whole program is done by the Program Evaluation Group which consists of Air Force colonels who have extensive experience in one or more mission areas. Collectively, they represent experience in all mission areas. The Program Evaluation Group looks at the proposed plans across the mission areas and renders its collective judgment on them. The group generates a proposed total program that conforms to fiscal guidance and promises to deliver optimum capability within cost and technological constraints.

Conducting the second level of review is the AFSC Council, which consists mainly of general officers and is chaired by the vice commander. This body reviews the Program Evaluation Group's output, renders additional judgments on major issues, and submits the total program to the commander. The commander carefully reviews the total program to ensure that there is an underlying rea of og'c in it, that there is consensus among

for acquisition and support make sense.

Once approved by the commander, the set of integrated and modified plans becomes the official proposed program of the Air Force Systems Command. Because the program has been formulated within dollar constraints using well-reasoned value judgments, it is balanced and traceable. Through marginal analysis, trade-offs across mission areas are done so that each issue can be viewed in the context of its competition in other mission areas. There is never a need to make a last-minute snap judgment out of context with the whole program.

In the formulation process, a set of plans has been transformed into a set of programs. In VANGUARD, the line of demarkation between plans and programs is intentionally obscured. The various annotations and conventions that the programmers have required are preserved during the planning process and the various levels of effort in program elements are structured in the required decision-package formats by the program managers so that the transformation of plans to programs is a coordinate transformation that can be done by computer. The dissolution of the boundary between planning and programming is a substantial side benefit of VANGUARD.

The coupling of the analysis and planning activities into the Program Evaluation Group a

System implementation

The plan for implementing VANGUARD at the Air Force Systems Command was largely tailored to existing organization and policies. Nevertheless, a substantial revision to the way the command approached its plans and programs was necessary. Up until that time, the planning staffs had concentrated on program incubation, that is, they concentrated on obtaining support for a concept, nurturing it through the bureaucratic wickets of the acquisition-review process, and handing it over to the systems staff as an established program. The procedure had the advantage of the planners' involvement in real programs; however, the extensive time devoted to program monitoring and administration was lost to planning, and the circumstances of program incubation tended to encourage an advocacy approach. To accommodate VANGUARD, the planners divested themselves of most of their programs. Transition of the program to the systems managers was moved up to coincide with approval to initiate advanced development, Milestone I of the acquisition-review process.

In order to be ready with VANGUARD by the FY81 Program Objective Memorandum submittal in January 1979, the Air Force Systems Command undertook to prepare the seven master mission-area plans in the headquarters. Members of the command's planning staff were individually assigned responsibility for specific master mission-area plans. Following some inter-product division negotiations, the field planning staffs were assigned primary and correlative responsibilities for each of the supporting plans. These field planning staffs also modified their program responsibilities to make room for VANGUARD. All 36 supporting plans were placed on a master schedule administered from AFSC headquarters.

The integration of the VANGUARD activities into the routine of program preparation and submission in Air Force Systems Command head-

the mission-area panels. Thus, the VANGUARD inputs became a major driver in the deliberations, along with the field recommendations and the panels' views. Statistical comparisons of VANGUARD inputs with program recommendations at the mission-area panel level show that VANGUARD inputs dominated. At the Program Evaluation Group and Council levels, the statistics show VANGUARD inputs as major contributors but not dominant.

Because the VANGUARD process addresses the difficulties of the past, is founded on fundamental tenets of good planning, and is built upon first principles with analysis, synthesis, and implementation, it can be said to be a complete planning system. Obviously, its success will depend not only on its inherent validity but also on the commitment of the people involved, particularly the AFSC Commander, to support it steadfastly over a period of several years before passing judgment on it. Many good ideas have failed, not from flaws in concept, but from half-hearted execution. How VANGUARD will ultimately fare is unforeseeable. Its long-term success depends on the continuing work of many experienced, intelligent, and educated people. Fortunately, VANGUARD contains provisions for self-assessment and self-correction. If it is successful, it will so signal; if it is a failure, it will recommend its own demise.

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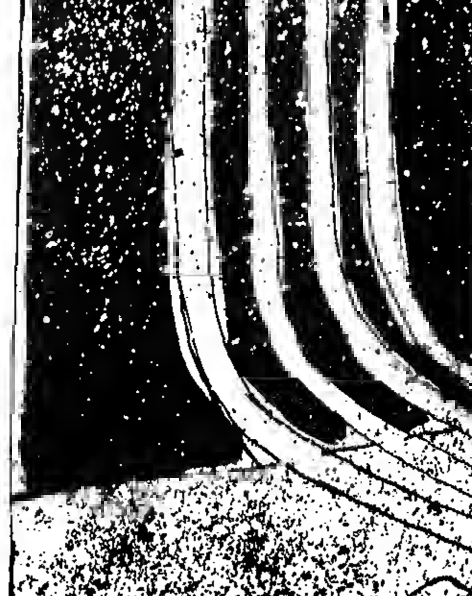
Quality circles forge a link between labor and management

A Japanese-originated labor-management innovation that taps the job-related wisdom of employees is being tested in the U.S.



West Germany and France have had an average growth rate of 4 percent, while the United States has averaged only 1.5 percent. This slow rate of American productivity growth is evident in the United States' loss of international market shares. In 1962, for example, the U.S. drug industry held 28 percent of the world market; today it holds a relatively meager 15 percent. Similarly, the U.S. aircraft industry held 66 percent of that international market in 1970; now it claims only 58 percent. Lagging productivity growth, high inflation rates, and decreasing shares of world markets are all contributing factors to the United States' fall from industrial pre-eminence. Lost shares of the world market weaken the dollar and increase the flow of imports. As our productivity growth curve flattens, American industry becomes less competitive. This curve almost stood at zero growth in 1979 and 1980.

By comparison, Japan's economy during the 1970s illustrates the positive effects that productivity improvements can have on combating inflation and ensuring a competitive trade advantage. During that 10-year period, price increases in Japan were relatively minimal, as reflected in the 30 percent increase in price of the popular Toyota Corolla and Datsun 210 cars. (When the cost of improved safety devices and emission controls are considered, the actual price rise was much less than 30 percent.) Although the price of steel doubled, these increases were considered relatively low when compared to ten-fold oil price hikes. In electronics, the average price of television sets decreased by 30 percent and power consumption was reduced. These results seem even more remarkable when compared to the quadrupling of average Japanese wages in the same time frame. The underlying reason for these results is that productivity increases had an offsetting effect on price increases, reducing them to reasonable levels.[1] Simply stated, the amount of production output per employee increased at a more rapid rate than the

In this regard, quality circles become the primary mechanism to improve the quality of products and services.

The emerging national debate on the causes and cures for declining American productivity has led to increased interest in quality circles as a means of intensifying employee concern and involvement in their jobs. In contrast to specific productivity initiatives such as value-engineering or cost-reduction programs, the key to the success of quality circles is in unlocking the fullest potential of employee contributions. Successful quality circles become a way of thinking: how to relate individual employees to their jobs and their firms, how to increase employee satisfaction, how to improve communication among employees. From the intangibles of untapped human resources may ultimately flow the benefits of improved quality, cost reductions, and increased productivity.

A recent motivational study of Social Security Administration employees reported that 96 percent of those surveyed felt highly motiviated from the feeling of achievement derived form doing challenging work well, and 94 percent were highly motivated by the inner drive to always try to do a good job. In addition, the study concluded that as a group, first-line supervisors do not understand the factors which motivate their employees.[2]

While the quality circle concept is not the ultimate solution to all motivational problems, the idea does facilitate employee involvement in meaningful tasks. In the role of circle leaders, first-line supervisors work with employees in an environment that provides first-hand experience in learning what motivates employees. In short, the quality circle concept permits employee involvement in important tasks, provides recognition for work well done, and encourages a participatory relationship between employees and supervisors.

Typically, American management focuses on short-term costs as management's answer to declining productivity. In Japan, management be-

corollary, obtaining the insights of the workers who know the product and process best is the soundest method for improving products and processes. A vice-president for quality at Douglas Aircraft summed up these linkages when he said, "Up to 40 percent of our aerospace work has to be reaccomplished because it was not right the first time."[3] Neither American industry nor the Department of Defense can afford such conditions.

The quality circle idea originated in Japan two decades ago. Until the late 1950s, the *Made in Japan* label generated an impression of a low-quality product. Accordingly, Japanese industrialists and government personnel sought to reverse the association of Japan with inferior-quality products. Their plan was to instill and develop a nationwide sense of total organizational involvement between workers and management to improve the quality of products and services.

By 1978, the number of registered and unregistered quality circles in Japan had grown to over 500,000, with an estimated membership in these circles of one out of every eight members of the Japanese work force.[4] After implementing the circle concept, the Gohei Tanabe Company, Limited, produced three times as much chemical PAS acid, of more uniform quality, with the same machinery, with less effort from manpower, and with the same input of raw materials. The change in quality resulted from quality circle-initiated proposals regarding variance analyses of temperature and pressure on the final product and the use of control charts on the purity of PAS. The Toyo Rayon Company, Limited, reduced the number of people previously required to repair flaws in cotton textiles from 500 to 50. Production quality improved as a result of quality circle personnel main-

[3] *Erwin J. Bulban, "Solution Sought for Production Lag,"* Aviation Week, *June 2, 1980, p. 50.*

[4] *Robert E. Cole, "Learning from the Japanese: Prospects and Pitfalls,"* Management Review, *September 1980, p. 26.*

[5] *W. Edwards Deming, "My View of Quality Control in*

Quality circles utilize the knowledge of those closest to productivity problems and help to ansure that solutions are both workable and tailored.

taining quality control charts and analyzing and correcting processes having multiple variations or flaws.[5]

The near-paternalistic relationship between Japanese workers and companies strengthened the growth of quality circles. The Japanese worker has a long and abiding commitment to the company. When one is being paid, housed, medically cared for, and fed through company facilities, the degree of worker involvement will be correspondingly high. Moreover, Japanese managers recognize that workers have the potential to make physical and mental contributions to the company.

The quality circle process is relatively simple. Workers form groups to define, evaluate, and resolve problems which will enhance the quality of small or large segments of a company's product line. For example, an automobile assembly line worker could help resolve a persistent problem of rusting by recommending that an external metal fastener be replaced with a plastic device. As workers are increasingly recognized for contributions, they become more enthusiastic and link their personal rewards and growth with the success of the company.

As a standard, the circle consists of no more than fifteen volunteer employees, with the first-line supervisor designated as the circle leader. Quality circle grou s normally meet at least twice a are instances where time has been donated by employees. Circle leaders use an agenda to guide meetings through a productive sequence of problem identification, problem solution, and presentation of solutions to management. These meetings should not be characterized as gripe sessions. Circle leaders guide the energies of the members toward achieving top-quality solutions and employee development. Facilitators are used to coordinate, monitor, and promote one or more of the circles; they may work on circle matters on a full or part-time basis, depending on the activity and management direction. This structure neither replaces nor alters existing formal or informal organizational structure. Rather, it supplements and supports the present organization.

Prior to the circle concept, only management identified and resolved problems. Now workers participating in the circle can also solve problems and improve the organization. In essence, the concept focuses on joint employee-management participation, involvement, and commitment in

for the implementation of good ideas.

Employee involvement must be strictly voluntary. Workers should be encouraged to think and grow mentally and should be rewarded for good ideas. For the circle concept to succeed, employees require concrete results and rewards from their efforts. Admittedly, the quality circle concept is not to be viewed as an incentive awards program. In fact, cash awards should be avoided. Instead, the entire circle should be recognized through organizational newspapers, circle photographs posted on bulletin boards, and circle nicknames printed on T-shirts for group members.

Perhaps the most important form of recognition is allowing a member to present circle recommendations to top management. Many workers never have this opportunity to converse with senior officials. In that the notion of being an important member of the team is contagious over time, circle members who are allowed to brief senior managers and who are accorded proper managerial recognition and plaudits are motivated to strive toward another presentation. But momentum is a necessary ingredient. Without management's enthusiastic support and recognition of circle activities, the quality circle concept will be no more than a forced, top-down management approach.

Naturally, the success of quality circles is contingent on the initial circle training program. Quality circle leaders and facilitators need to learn effective group dynamics, the application of problem-solving models, and basic statistical methods. Group leaders are responsible for training employees who join the circle. Middle- and senior-level managers must be included in the initial training program and in the establishment and operation of circles. Similarly, union participation and support is a prerequisite to the development and continuance of a circle project.

A standard training program can be developed internally or through contract. Some management consulting firms have prepared quality circle training packages that cost approximately $200 per stu-

in U.S. organizations are encouraging, but the effort has not been easy. Despite the fact that approximately 100 U.S. firms [6] have been experimenting with this technique for nearly six years, the success rate does not parallel Japan's experience. The reasons for slower U.S. progress are based on differing employee commitments and relatonships to the corporation, dissimilar management approaches and beliefs regarding the capabilities of individuals, and the contrasting roles of unions. Although these differences have posed obstacles, they have not precluded circle implementation. For example, successful programs have been achieved at a General Motors plant, where one analysis is saving $225,000 annually.[7] In the first two years of circle operations, Lockheed has documented savings at $2.8 million; in one operation alone, circle recommendations reduced rejects from an original 25 to 30 per 1,000 hours to less than 6 per 1,000 hours.[8]

A foundation for implementing the quality circle concept in the U.S. has been established, and some would say none too soon. Productivity improvements such as quality circles are being recognized as vital weapons to combat inflation and could become an important management tool for the 1980s.

Adapting the Japanese approach to reflect U.S. differences in employee commitment and management philosophies is crucial. Such an adaptation would certainly include broadening circle attention beyond the parameters of improving product reliability. The widened perspective could encompass such divergent dimensions of productivity improvements as quality of work life, labor-saving capital equipment, facilities improvements, work methods, and process flow. Circles should concen-

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[6] Robert E. Cole, p. 27.

[7] *Earl C. Gottschalk, Jr., "U.S. Firms, Worried by Productivity Lag, Copy Japan in Seeking Employees' Advice,"* Wall Street Journal, *February 21, 1980.*

[8] *Ed Yager, "A Participatory Technique that Benefits Trainers, Managers and Employees Alike,"* Personnel Jour-

with diverse capabilities. Admittedly, the quality circle concept has primarily been oriented toward blue-collar workers, but the growth of the program into the white-collar enclave would appear to be a logical extension.

A recent survey by the General Accounting Office found that thirteen federal installations have operational quality circle programs. The U.S. Army Depot System Command recently initiated a quality circle program called Participative Work Improvement Circles. With more than fifty circles now in operation, the Depot System Command approach is an expansion of the somewhat restrictive Japanese definition of quality circles and includes many productivity improvement possibilities, including experiments for some white-collar jobs. The Norfolk Naval Shipyard in Portsmouth, Virginia, is a pioneer with more than 50 active circles. To date, their program has resulted in savings of \$3.75 for every dollar invested, with a net program savings of \$150,000[9] in the first year of operation. If federal agencies would only learn from the circle experiences of U.S. corporations, government application could be implemented more quickly than the six-year time frame experienced by corporations.

Despite these positive examples, universal application of the circle principle to DoD elements should not be inferred. The concept is suited predominantly to civilian organizations. Nonetheless, an innovative approach to structuring a quality circle program could prove beneficial to almost any organization, including a headquarters-type operation.

In developing and implementing the quality circle concept, there are prerequisites which should be recognized and accepted as integral program components.

- Management must maintain a visible long-term commitment to the program. Circles take from 3 to 12 months to reach a productive state.

[9] Joe M. Law, "Quality Circles Zero in on Productivity at the Norfolk Naval Shipyard," Management, Summer 1980,

- Quality circle implementation and management must permit program survival during management transitions to prevent situations where employees might be reluctant to renew circles.
- Management must rely on volunteer and internal resources to operate and support the program.

The quality circle concept has a long and successful history in Japan and continues to grow. In the United States, the concept is beginning to gain acceptance, and increasing inflation rates and negative productivity trends will probably accelerate application of the program. Use of the concept in the Department of Defense is in the initial stages of activation, and the potential for success is just beginning to be realized. DMJ

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Computer-based instruction for military training

In the modern military classroom, blackboards and lock-step instruction are giving way to computer terminals and self-paced lessons.

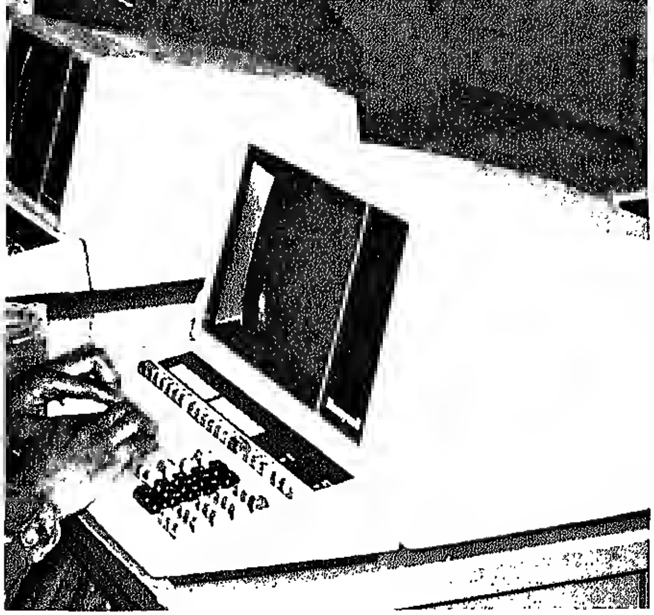
It is no secret that special knowledge is needed to operate and maintain modern military systems, and that military schools and training courses are designed to provide that knowledge. It is less obvious, but very important to understand, that the advanced performance capabilities built into new military systems will be realized only if our military personnel are adequately trained to properly operate and maintain these systems. Clearly, military training must provide a high-quality product.

Accomplishing the training mission is neither easy nor cheap. In fiscal year 1981, the annual cost of individual training for active-duty and reserve-component personnel is approximately 8.8 billion dollars. About 74 percent of this training mission is related to new active-duty accessions.

Another way to appreciate the magnitude of the military training problem is to note that these figures reflect only the types of training that take types of training are very expensive and add to the costs described above; it is also important to know that they strongly influence military readiness.

Students may be instructed by a number of means, including lectures, discussions, tutelage, independent study, and drill and practice. For purposes of this discussion, the methods of instruction have been categorized into four groups. In actual practice, more than one method of instruction may be used in a course.

Conventional instruction. Conventional instruction involves combinations of lectures, discussions, laboratory exercises, and tutorial sessions. A key feature of conventional instruction is that groups of students proceed through a course at the same pace. Differences in the amount of information retained by students are reflected in the students' final grades. Conventional instruction is also referred to as lock-step instruction, platform instruction, and group scheduling. It is used in 75



U.S. ARMY PHOTO

pace. Each lesson is associated with a test. Mastery of each lesson is required as a condition of progress. Differences in student performance are reflected in the amount of time taken to complete a course, although grades may also be given.

Various versions of individualized instruction may differ in such ways as the order in which lessons are provided to the student and the extent to which the student is completely free to proceed at his own pace. All methods of computer-based instruction rely on some form of individualized instruction. In this discussion, individualized instruction refers only to individualized instruction conducted without computer support.

Computer-assisted instruction (CAI). Computer-assisted instruction is a form of computer-based instruction. In it, the student interacts in real time, via an interactive terminal, with instructional material that is stored in the computer. This offers great flexibility for presenting alternative versions of the same lessons according to each student's particular way of learning.

Operation (PLATO). The current version of this system, PLATO IV, can support about 950 terminals linked through microwave and land-line communications to a large central computer. PLATO originated at the University of Illinois. Each terminal has a cathode ray tube and a typewriter keyboard. A stand-alone version, with only one terminal, has just been shown publicly.

- *Time-Shared Interactive Computer-Controlled Information—Television (TICCIT).* The basic TICCIT system uses one or two minicomputers to support up to 128 terminals at one location.
- *General Electric Training System (GETS).* This is a stand-alone system with only one terminal that uses a random access 35-mm slide projector for visual displays and floppy discs for lessons and playback.
- *Computer-managed instruction (CMI).* Computer-managed instruction, like computer-assisted instruction, is a form of computer-based instruction, although the actual instruction takes place away from the computer. After each lesson, the student takes a test and places the answer sheet on an optical scanner. The computer scores the tests and interprets the results. The student receives a printout that indicates how well he or she performed, what lesson is next, and where to find the next lesson. The computer also manages student records, instructional resources, and administrative data. Examples of some CMI systems include:
- *Advanced Instructional System (AIS).* This is a prototype system installed at the Air Force Technical Training Center, Lowry Air Force Base, Denver, Colorado. It contains 50 student terminals, 11 management terminals, and a CDC CYBER 73-16 computer which can support up to 3,000 students a day in four courses. These courses, selected to represent a cross section of the technical training courses at Lowry AFB, can serve about 25 percent of the student body. The management terminals are used by instructors for retriev-

student achievement with computer-based Instruction was the same as with conventional instruction in 32 cases and superior in 15 cases.

Computer-Assisted Instruction	Inferior	Same	Superior
IBM 1500			
Electronics (A)		●●●●	●
Electricity (N)			●●●●●
PLATO IV			
Machinist (A)		●●●	
Electronics (N)		●●	●●●●
Recipe Conversion (N)		●●	
A/C Panel Operator (N)			●
Medical Assistant (AF)		●●	●●
Vehicle Repair (AF)		●●●●	
LTS-3			
Electronics (AF)		●●	●
Weather (AF)		●	
TICCIT			
Tactical Coordination (N)		●	
IDIOM			
Fire Control Technician(N)	●	●	
PLATO IV			
Fire Control Technician (N)		●●	
Computer-Managed Instruction			
NAVY CMI			
Aviation Familiarization (N)		●●	
Av. Mech. Fundamentals (N)		●●	
AIS			
Inventory Management (AF)		●	
Materiel Facilities (AF)		●	
Precision Measuring Equipment (AF)		●	
Weapons Mechanic (AF)		●	

• *Computer Managed Instruction System (CMI).* This system, installed at Naval Air Technical Training Center, Millington, Tennessee, handles about 6,000 students in 11 schools at 5

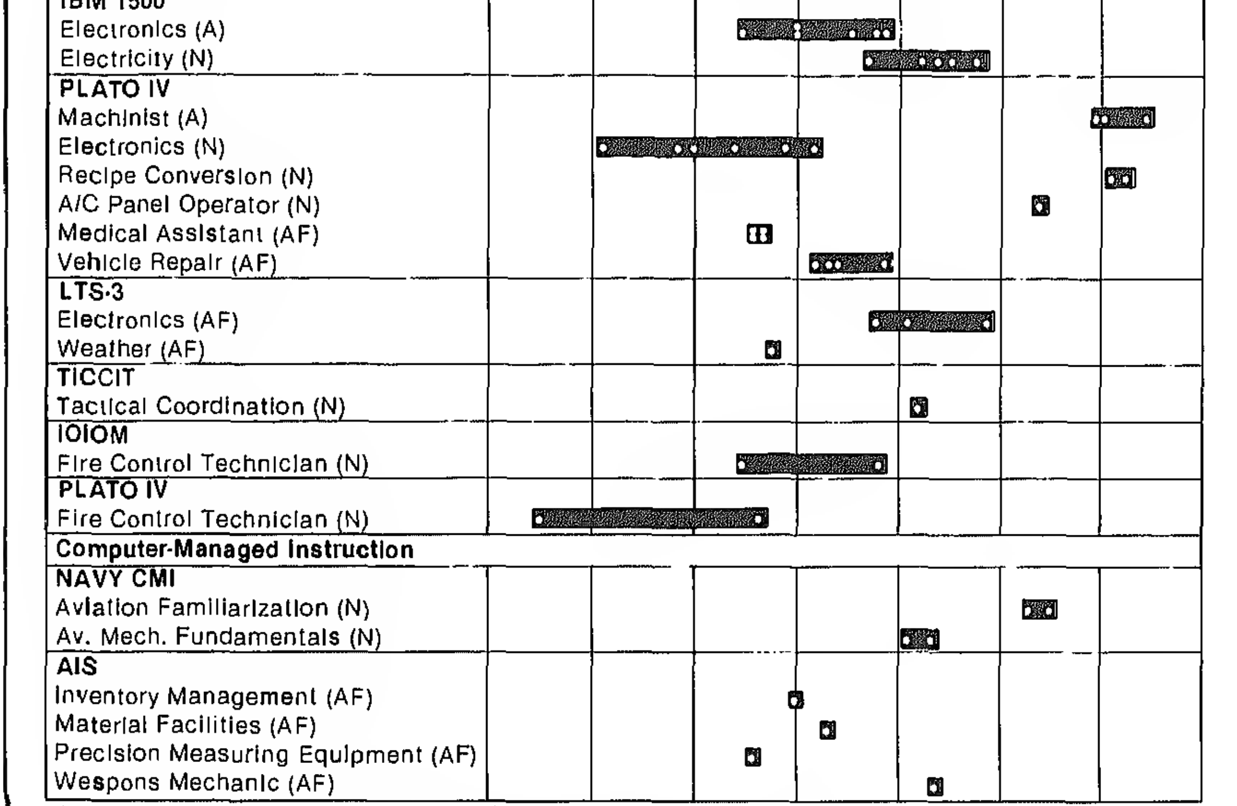
management services.

Military personnel receive pay and allowances while they are being trained. Thus, any procedure that can reduce the time required for training, without significantly affecting the amount or quality of information acquired by the students, can reduce the cost of training. It can also increase the amount of time military personnel spend in operational assignments during their military careers. Military training courses are designed to qualify students for well-defined jobs to which they can be assigned upon successful completion of these courses.

This situation differs from that in most public and private schools, where students remain at school for required periods of time and are not paid while there. These schools receive no direct benefits if students complete their instruction in less than the required time. Courses are generally not designed to qualify students for particular jobs and the schools cannot assign students to jobs upon graduation.

A revelation found in these distinctions is that methods of instruction that are cost-effective for the military may not be cost-effective for other sectors. Another is that service-supported research on computer-based instruction has emphasized the feasibility of saving student time while maintaining a constant level of student achievement. Research on instruction in non-military settings has focused on student achievement at school and has not emphasized the amount of time needed by students to absorb the material.

The military services have supported research and development of computer-based instruction since the early 1960s when the concept first appeared feasible. Computer-assisted instruction and computer-managed instruction in military training have been evaluated in about 30 studies since about 1968. These studies generated 48 sets of data. Most of these studies were of a research



*Direct comperisons between CAI and CMI were not mede, however.

these studies to properly interpret the data they provide.

Military training is intended to prepare personnel to perform various jobs in operational commands. Thus, the effectiveness of any method of instruction should be evaluated by measuring how well a course graduate performs certain designated jobs in the field. This is done by comparing the job performance of individuals trained by conventional instruction with the performance of those trained by computer-based instruction. There are few studies that provide this type of information. Most studies of different instructional methods compare only student achievement at school, as measured by tests administered at school. This

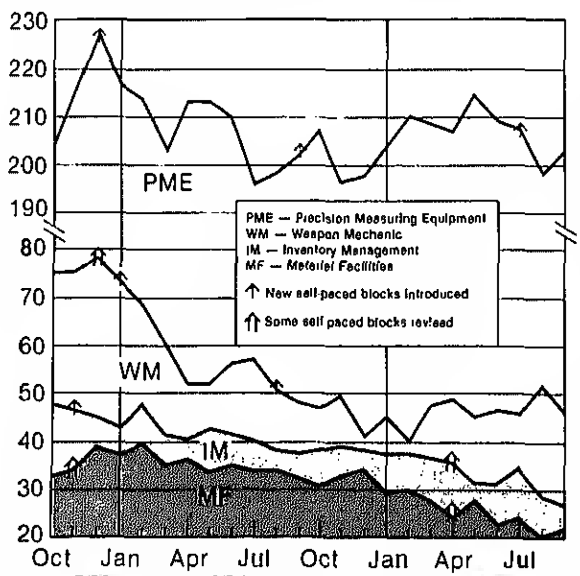
Most studies were experimental in nature. About half involved 50 or fewer students and about half the courses studied lasted one week or less. In a few studies, the courses spanned as much as 10 months and involved 600 to 2000 students. The courses embraced a wide variety of subject matter. Many were directly related to technical training, basic electronics, and electricity; some involved hands-on maintenance checkout and repair. No single course was given by both computer-assisted instruction and computer-managed instruction. This means that the effectiveness of computer-assisted instruction and computer-managed instruction for the same course cannot be directly compared.

as achievement at a school with conventional instruction.

Data on the amount of student time saved through the use of CAI and CMI, as compared to conventional instruction, are shown in Figure 2 (p. 49). The amounts saved are considerable, and the median value is about 30 percent. No particular significance can be attributed to differential time savings between CAI and CMI shown in these data because, as noted above, direct comparisons using the same courses were not made. A major uncontrolled variable in these studies is the unknown quality of the instructional materials used in the various comparisons. This limits any attempt to make quantitative comparisons about the amount of student time saved by different types of CAI or CMI.

Figure 3. Course completion times at Lowry AFB

This figure shows the time saved by about 11,000 students in four courses on the Air Force Advanced Instructional System between October 1976 and September 1978.

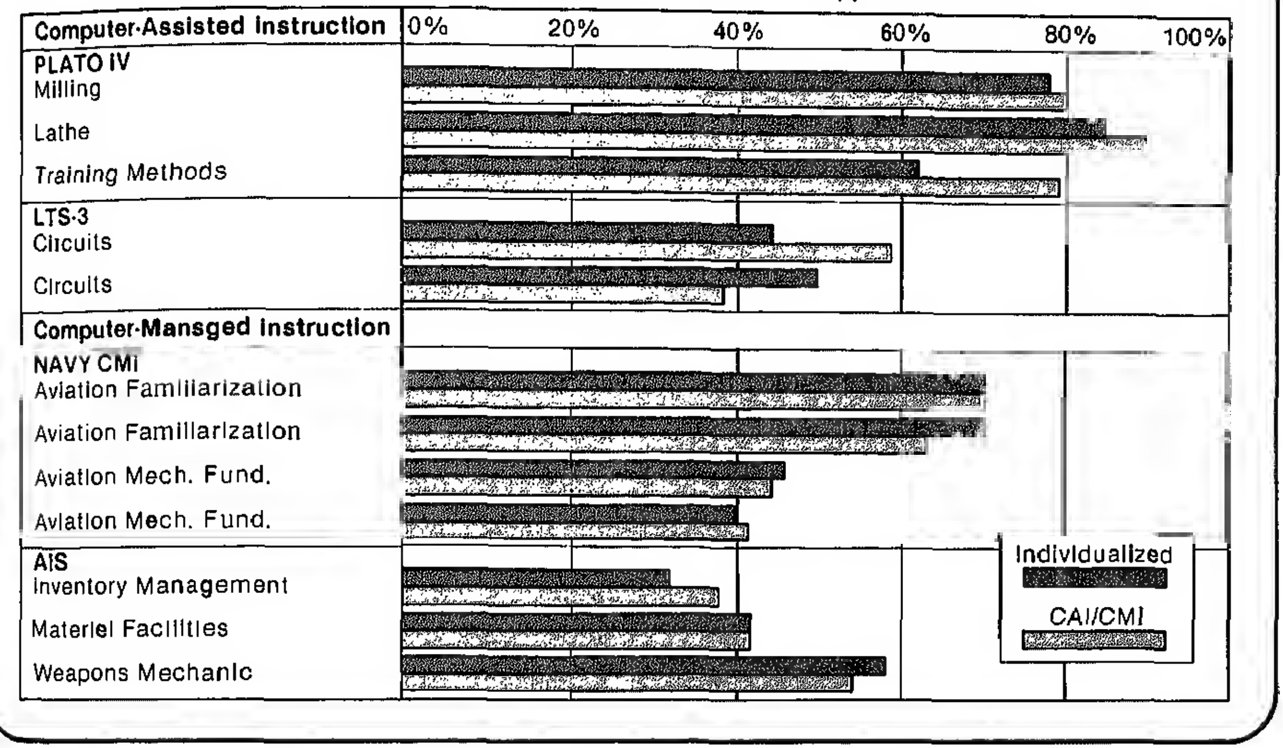


course. In conventional instruction, where there is a fixed amount of time, these differences lead to variations in the amount of knowledge acquired by the end of the course.

Both in individualized and computer-based instruction, each student proceeds at his own pace, and differences between students influence the amount of time needed to complete the course. Differences in the amount of information acquired are not a major variable. The bulk of the time savings in individualized instruction is produced by those students for whom the rate of progress set in conventional instruction would be too slow. Typically, that rate might be one that permits about 90 percent of the students to complete the course during the fixed period of time; it is, in fact, a rate set to meet the needs of the slower, rather than just the average, student.

Almost all the aforementioned data represent time savings found in experiments or operational applications over short time periods and with limited numbers of students. Figure 3 shows time saved by about 11,000 students in four courses on the Air Force Advanced Instructional System, at Lowry AFB for 24 months ending September 1978. It is clear that the initial savings, such as might be reported in an experiment, are maintained over time and, despite monthly fluctuations, tend to increase. These reductions are probably attributable to periodic revisions in the courses and to improved control over the new method of instruction; fluctuations are probably attributable, at least in part, to variations in student aptitude as well as to other factors that are presently unknown.

Student training time in courses can be reduced without the use of computer-based instruction, such as through individualized instruction without computer support in place of conventional instruction. This prompts one to question what it is that computer support does that self-pacing does not, at least in the context of student time saved.

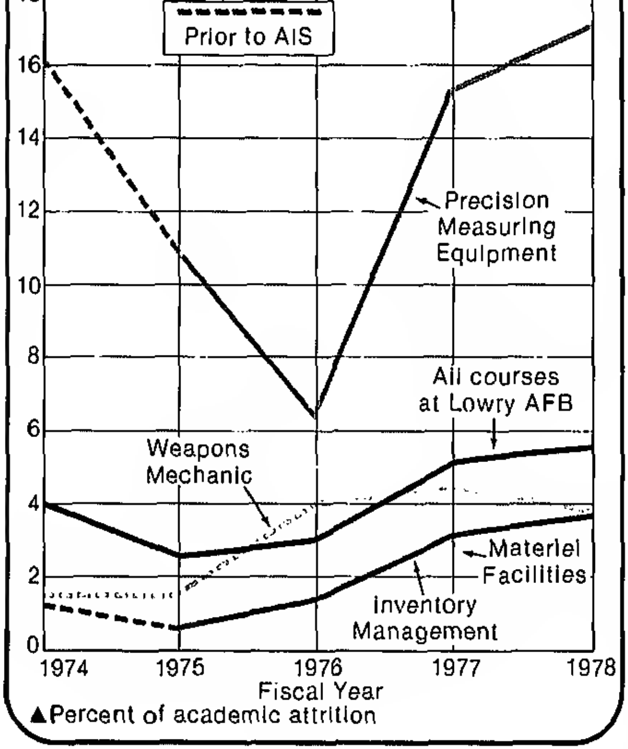


ven at various times, by conventional, individ-lized, and CAI or CMI instruction. (Only the rcent time saved, compared to conventional struction, is shown.) There are only relatively nall differences between the amounts of time ved by individualized and by CAI or CMI struction. Individualized instruction can save uch of the time normally required by students in nventional instruction. (There were average sav-gs of 50 percent or more in these samples.)

The addition of computer-assisted instruction to ve individualized courses yielded an additional erage time saving of 5 percent; the addition of mputer-managed instruction to seven individ-lized courses produced no additional time sav-g. No significance can be placed on the differen-l effect of adding CAI rather than CMI to the se values because no course was given in both a

on several factors, including its specific application, the numbers of instructors and support personnel, and the administrative costs. The issue of cost is not addressed here.

Since the method of instruction may influence the number of students who can successfully complete a course, the rate of academic attrition associated with alternative methods of instruction is a matter of concern. Meaningful data on student attrition should come from a steady-state application of computer-based instruction and not from short-term experiments. This condition was met marginally by the Air Force Advanced Instructional System, where four courses at Lowry AFB were increasingly implemented on a computer-managed instructional system over a five-year period and by the Navy Computer Managed



tation in March 1977. It should be recognized that the rate of attrition observed in a course may be influenced periodically by policy decisions on recruitment standards and on the number of graduates to be produced by various courses. Such influences are not addressed here.

Figure 5 shows that academic attrition may have increased in the four courses on the Advanced Instructional System when they were being implemented in a computer-managed instruction mode. However, it should be noted that academic attrition appeared to rise in all courses at Lowry AFB during that same period. Thus, it is not determinable if the increased attrition in the Advanced Instructional System courses is largely attributable to the introduction of computer-managed instruction or to other factors, such as changes in student

Advanced Instructional System and the Navy Computer Managed Instruction System, have received any kind of use in military training. It does appear, however, that academic attrition may have increased slightly in courses taught in this mode as compared to the conventional mode. Since these comparisons do not take into account possible changes in the qualifications of students during the observed periods, the available data suggest but do not prove that computer-managed instruction leads to greater academic attrition than does conventional instruction.

Attitudes of students and instructors on CAI and CMI, in comparison to their attitudes on conventional instruction, should be viewed as qualitative aspects of these methods of instruction. They are not necessarily measures of effectiveness. Data on student attitudes were generated by 39 of the 48 reports of military training cited in this paper. The data reflect that students overwhelmingly prefer CAI or CMI to conventional instruction, or at least say so when asked. Student responses were favorable to computer-based instruction in 29 of 40 comparisons; they were unfavorable in one case. One other response indicated no difference. No data are provided in nine cases.

Instructor attitudes are reported only in nine of these 48 comparisons. Instructors were negative toward CAI and CMI in eight of these cases and favorable in only one.

Instructors of courses taught by CAI or CMI have not received much attention from researchers. The training of instructors is still oriented largely toward conventional instruction and instructors receive little guidance on how to properly conduct courses given by computer-assisted or computer-managed instruction.

There have been only a few attempts to estimate the cost-effectiveness of computer-assisted instruction and computer-managed instruction, and

No. Island (N)	67	200 pilots per year	$0.57M
Chanute (AF)	19-27	375 per week	PLATO IV not as cost-effective as programmed instruction
Conventional (revised course)			
Memphis (N)	50	300 per class per week	$6M
Navy CMI			
Memphis (N)	41-70	300 per class per week	$3M
Memphis (N)	—	— — 52,672 graduates (actual)	$ 8.9M FY 75 $ 9.6M FY 76 $10.0M FY 77
AIS			
Lowry (AF)	24-36	21,128 (actual)	1417 m/years $6M (4 yrs)
Lowry (AF)	10-52	5,561 (actual)	710 m/years $3M
Lowry (AF)	– 3.6-12.5	—	AIS cost-effective compared to instructor-supported self-pacing on one course, not in others; computer costs small compared to other school costs.

these are based on incomplete analyses of the costs of instruction. A summary of the results of these studies is provided in Figure 6. All of these studies were based on the premise that the amount of student training time saved by a method of instruction represents a major cost savings. The amounts of cost savings were estimated by computing the pay and allowances of students for the amounts of student time saved in training. The resultant amounts could more appropriately be called *cost-avoidance* savings. This procedure was applied to student time savings in studies of three major instructional systems and of revised course materials in a conventional-instruction course. Some of

$3 million a year for about 5,500 students instructed in FY78 by the Air Force Advanced Instructional System. According to two cost-effectiveness evaluations, the Army PLATO IV System was judged to be not as cost-effective as individualized instruction.

These conclusions are based on incomplete cost data in two small-scale tests, one involving 535 students in four courses at the U.S. Army Ordnance Center and School and the other involving 1261 students in four courses at Chanute AFB, Illinois. The Air Force Advanced Instructional System was found to be cost-effective, compared to instructor-supported, self-paced instruction in one course but not in three others. The computer costs which made the latter courses not cost-effective were actually small in comparison to other school costs. Since all of these results are based on incomplete cost data, the findings should not be generalized or taken as conclusive.

Other benefits, beyond those of saving student training time, are often said to occur with computer-assisted instruction or computer-managed instruction, largely because of services that can be provided by a computer. These benefits include:

- More precise data for improving and updating course materials.
- Improved control over equipment, facilities, and instructional materials.
- Improved allocation of resources among students.
- Improved ability to accommodate fluctuations in student loads.
- Reduced instructor-to-student ratios.
- Reduced need for support by non-instructor personnel.
- Improved utilization of instructors.

Few of these potential benefits have been examined in cost-effectiveness evaluations. The 1978

amounts of time spent by students at Lowry AFB waiting to enter a course and waiting for an assignment after completing a course have been reduced. Records kept by the Navy Computer Managed Instruction system show that the average on-board count of students in school has also been reduced for those instructed by that system. However, the cost savings, if any, implied by these reductions were not included in any of the cost-effectiveness analyses.

In closing, it should be acknowledged that the effectiveness of computer-assisted and computer-managed instruction for military training has been measured only by student achievement at school and not by performance on the job. Correlations between performance at school and on the job have not been established for any method of instruction. Also, student achievement in courses at military training schools using computer-assisted instruction is the same as or greater than that achieved with conventional instruction. The amount of additional achievement is small and has little practical importance. Student achievement in courses with computer-managed instruction is about the same as that with conventional instruction. Both of these results stem from the fact that students are kept in CAI and CMI courses until they achieve standards set for conventional instruction.

Along similar lines, computer-assisted and computer-managed instruction in military training save about 30 percent of the time normally needed by students to complete the same courses given by conventional instruction. The amounts of student time saved by computer-based instruction vary widely, yet little attention has been given to the factors that could account for the variations. Most of the results on computer-assisted instruction come from experiments of limited duration, with limited amounts of course materials, and with relatively few students. Where computer-managed instruction has been used for extended periods of up to 4 ears the initial time savin s have con- increase the rate and costs of student attrition for academic reasons over those resulting from conventional instruction. However, the observed increases in attrition may also be due to decreases in student quality. Only limited and incomplete data are available on the costs of computer-assisted and computer-managed instruction in military training. Data that are collected routinely on the costs of operational training programs are too highly aggregated, particularly with respect to training support functions, for use in analytical comparisons of computer-based instruction with conventional instruction.

Estimates based on the amounts of student time saved suggest that the Navy Computer Managed Instruction System avoided costs of about $10 million in FY77 and that the Air Force Advanced Instructional System avoided costs of about $3 million in FY78. These estimates are incomplete because they do not consider all of the costs of providing computer-managed instruction at these installations nor do they compare these costs with the costs of alternative methods of instruction for the same courses.

Overall, the existing evidence, despite its sprinkling of shortfalls and uncontrolled variables, tends to verify the value and suitability of computer-based training in the military. DMJ

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Plans to improve military retention

If the Congress approves military pay raises proposed for July and October 1981, the services should turn their attention to bonuses and improved living conditions in order to *induce people to join* and stay in the military. Lawrence J. Korb, Assistant Secretary of Defense for Manpower, Reserve Affairs, and Logistics, expressed that view in a briefing prepared for the American Enterprise Institute, a Washington-based think tank. Mr. Korb served as AEI's director of defense studies before being named the Pentagon's manpower chief.

The raises—5.3 and 9.1 percent, respectively—should enable the services to attract recruits in most lines of work, Korb said. In shortage areas, he advocated use of bonuses to get people to re-enlist and acknowledged that changes to the military pay system may be necessary to meet the demands of the marketplace for skilled workers.

Quality of military life, according to Korb, is nearly as important to morale as pay, and higher morale will in turn raise retention rates. He noted that the Reagan administration budget calls for a 15-percent increase in items which affect quality of life. These include family *housing, medical and den*tal care for dependents, reimbursement for moving expenses, and maintenance of housing and working facilities. When added to increases in pay, the 15-percent boost means more than a 40-percent increase overall in expenditures for military *manpower items.*

FY81 and FY82 pay increases should give the all-volunteer force a chance to work, Korb added, noting that pay caps and inflation since 1972 have hamstrung the AVF. The country should not return to a draft until the AVF has had a fair chance to work, he stated. The assistant secretary went on to say that even if the country does return to conscription, the military will need money to retain skilled people, and DoD may have to adjust the pay system to increase retention.

Reserves test longer training stint

A test program to be conducted this summer will try to assess the effect of a three-week annual training period on reserve components. Officials say that in some cases, the two-week an*nual* training period now used is not long enough to meet all objectives. They believe that an additional week will help improve unit readiness.

The program will look at [illegible] ing period on members of the unit, their families, employers, and communities. Also studied will be the impact of three week's training on the unit's ability to deploy for a longer exercise.

A unit from the Indiana National Guard's 38th Infantry Division volunteered to take part in the program and will deploy to Europe for the three-week period.

Guidelines for DoD decisionmakers

Secretary of Defense Caspar W. Weinberger today announced significant changes in the Planning, Programming and Budgeting System of the Department of Defense. "My objective," the secretary stated, "is not only the revitalization of American military strength but also to be sure it is accomplished in the most effective and economical manner."

He added, "I believe these changes will increase public and congressional confidence in our capability to match military requirements with military strength and simultaneously reduce costs and save the taxpayers money."

The changes are modifications of the existing system and reflect a shift to greater emphasis on long-range strategic planning, more responsibility [illegible] tralization, closer att[illegible] tion to cost savings a[illegible] efficiencies, and gene[illegible] streamlining of the proce[illegible]

Mr. Weinberger note[illegible] that the previous adm[illegible] istration introduced t[illegible] Zero-based Budgeti[illegible] (ZBB) concept in order t[illegible] show decisionmakers ex[illegible] actly what would happe[illegible] if they cut or added to th[illegible] budget.

However, the secreta[illegible] pointed out that the leve[illegible] of detail required unde[illegible] ZBB did not turn out to b[illegible] meaningful to senior man[illegible] agement. The enormous amount of paperwork in[illegible] volved served no tangible purpose. The secretary did acknowledge that the ZBB concept of reexamin[illegible] ing the necessity and de[illegible] sirability of continuing each program is a good one.

The new management strategy of the DoD lead[illegible] ership will place greater responsibility on the Sec[illegible] retaries of the Army, Navy and Air Force for the de[illegible] velopment and manage[illegible] ment of their segments of the Defense Department program. The service sec[illegible] retaries have been added to the top management board of the Department— the Defense Resources Board.

Under the new strategic planning system, the Joint Chiefs of Staff take responsibility, along with the Under Secretary of De[illegible] fense for Policy, for deve[illegible] oping more comprehen[illegible]

military objectives, policies, and strategies. There will be close attention to the resource implications of these policies in order to close the gap between military requirements and resources budgeted.

Within the given policies and resources, the secretary will look to the services to recommend the best way to meet the objectives within their budgets. The secretary will also maintain a strong central staff to assure cross-service programs analysis and thus guarantee the fullest and best use of budgeted dollars throughout DoD.

Navy taps enlistees for pilot training

The Navy began sending enlisted personnel to flight school in April for the first time in recent years. In order to make up for a shortage of pilots, enlistees in pay grades E-5 through E-7 are now eligible for training at the Navy flight school in Pensacola, Florida.

"These people will get the same training as everyone else," said Vice Adm. George E. R. Kinnear 2d, commander of the Atlantic Fleet Naval Air Force. "They won't get their wings unless they meet the standard."

The retention rate for Navy pilots dropped from 62 percent in 1977 to 46 percent in 1978 and 31 percent in 1979. Pre... Defense Department figures show that the Navy needs some 3,600 more pilots and about 400 more flight officers than are currently on board.

More opportunities for small R&D firms

The Department of Defense has announced establishment of a Defense Small Business Advanced Technology Program to capitalize on the potential of small, high-technology firms.

The program is designed to promote innovative solutions to scientific and technical problems facing the defense community by increasing the participation of small, high-technology firms in the department's research and development initiatives. The program is not a substitute for current unsolicited proposal mechanisms. It is designed to augment existing acquisition processes and to better inform DoD research offices of the technological potential of the small-business community.

Approximately 20 research and development project areas of particular interest to the Army, Navy, Air Force, and Defense Advanced Research Projects Agency will be identified for exploration under a three-phase program. A key feature of the program is its streamlined procedure for reducing the cost of ... investment in proposal writing. Phase I proposals are limited to 20 pages.

Phase I awards of up to $50,000 each are contemplated for preliminary research and development to demonstrate the feasibility of those proposals deemed most likely to yield solutions to R&D problems. Contracts under Phase I will last for six months. Under Phase II, DoD plans to award advanced-development contracts ranging from $100,000 to $500,000 each for a period of up to two years for Phase I projects judged most promising. Phase III will include follow-on DoD production awards, commercial application of the research and development, or a combination of the two. Commercial application would be funded with private venture capital.

Program information may be obtained by writing to: Director for Small Business & Economic Utilization Policy, Office of the Under Secretary of Defense, Research and Engineering (Acquisition Policy), Room 2A340, The Pentagon, Washington, DC 20301.

Reservists get active-duty option

The Department of the Army is offering Reserve and National Guard second lieutenants the option to serve three-year ... new program designed to fill a substantial number of vacancies in the active ranks. This opportunity is available to second lieutenants of all branches except the Medical Services Corps, Nurse Corps, Chaplain candidates, and other special branches.

Although selection for a three-year active duty tour cannot be guaranteed to all applicants, Army officials state that the large number of available positions makes chances excellent for interested and qualified second lieutenants.

For further information call toll free (800) 325-1874 or AUTOVON 693-7623/7207.

Temporary freeze on women in uniform

The Army has decided to freeze temporarily the number of women in uniform while reassessing their impact on readiness. Current plans are to stabilize the number of women at 65,000 through fiscal year 1987, which will result in a cumulative shortfall of 22,500 recruits.

Field commanders have reported growing problems with women coping with the strength and stamina requirements of some specialties. An additional consideration that led to this decision was the results of an Army study indicating wildly fluctuating attrition figures for women in differ...

Event	Date	Place	Contact
An Integrated Management System for Managers in Electronics	May 27-29 May 27-29 Sep 16-18 Nov 4-6	New York, NY New Jersey, NJ Chicago, IL Boston, MA	EIA Education Suite 405 2001 Eye Street, N.W. Washington, DC 20006 (202) 457-4996
The Next 20 Years In the Defense Industry	Jun 1	Boston, MA	AIAA Seminars (Dept. DI) P.O. Box 91295 (5959 W. Century Blvd.) Los Angeles, CA 90009 (213) 670-2973
Contract Pricing Techniques	Jun 1-5 Jul 20-24	Washington, DC San Francisco, CA	American Graduate University 733 North Dodsworth Ave. Covina, CA 91724 (213) 966-4576
Basic Project Management	Jun 8-11 Nov 2-5 Oct 12-15	Washington, DC Washington, DC Chicago, IL	American Management Associations 135 West 50th Street New York, NY 10020 (212) 246-0800
Operational Availability and Maintainability Engineering	Jun 22-26	Los Angeles, CA	Continuing Education In Engineering & Math 6266 Boelter Hall UCLA Extension Los Angeles, CA 90024 (213) 825-1047
Reliability and Life Testing	Aug 10-14	Los Angeles, CA	
Technical Writing Course	Jul 14-30	Washington, DC	Special Programs Graduate School, USDA 277 National Press Building 529 14th Street, N.W. Washington, DC 20045 (202) 447-3247
Systems Acquisition Management Conference	Jul 15-17	Washington, DC	National Institute for Management Research P.O. Box 3727 Santa Monica, CA 90403 (213) 450-0500
Software Engineering Principles	Aug 3-14	Monterey, CA	Ms. Janet Stroup Code 7590 Naval Research Laboratory Washington, DC 20375 (202) 767-2774